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Northeast Energy Efficiency Partnerships

MID-ATLANTIC
TECHNICAL REFERENCE MANUAL
VERSION 2.0

A Project of the Regional Evaluation, Measurement and Verification Forum

July 2011

Prepared by Vermont Energy Investment Corporation (VEIC)

Facilitated and Managed by Northeast Energy Efficiency Partnerships

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PREFACE

The Regional EM&V Forum

The Regional EM&V Forum is a project managed and facilitated by Northeast Energy Efficiency Partnerships, Inc. The Forum's purpose is to provide a framework for the development and use of common and/or consistent protocols to measure, verify, track and report energy efficiency and other demand resource savings, costs and emission impacts to support the role and credibility of these resources in current and emerging energy and environmental policies and markets in the Northeast and the Mid-Atlantic region. For more information, see http: www.neep.org/emv-forum.

Acknowledgements

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Subcommittee for the Mid-Atlantic TRM

A special thanks and acknowledgment from Elizabeth Titus on behalf of the EMV Forum staff at NEEP and project contractors at VEIC is extended to this project's subcommittee members. These individuals provided important input and guidance throughout the development of this TRM: Eugene Bradford (Southern Maryland Electric Cooperative), Daniel Cleverdon (District of Columbia Public Service Commission), Kristy Fleischmann (Baltimore Gas & Electric), Brian Gallagher (Consultant to Delaware State Energy Office), Dennis Hartline (Maryland Energy Administration), Cheryl Hindes (Baltimore Gas & Electric), Jeff King (Metropolitan Washington Council of Governments), Ruth Kiselewich (Baltimore Gas & Electric), Huilan Li (Maryland Public Service Commission), Teri Lutz (Allegheny Power), Laura Magee (PEPCO Holdings, Inc.), Ed Miller (Allegheny Power), Gary Musgrave (Allegheny Power), David Pirtle (PEPCO Holdings, Inc.), Charlie Smisson (Delaware State Energy Office), Mary Straub (Baltimore Gas & Electric), Steve Sunderhauf (PEPCO Holdings, Inc.), Lauren Swiston (Maryland Energy Administration), Sheldon Switzer (Baltimore Gas & Electric). In addition, staff from Itron, Navigant, GDS, Lockheed Martin,

and ICF have provided support to EMV Forum members of the subcommittee with this effort.

INTRODUCTION

This Technical Reference Manual is the outcome of a project conducted for the Regional Evaluation, Measurement and Verification Forum ('the EMV Forum') sponsored by Maryland, Delaware and the District of Columbia. The intent of the project was to develop and document in detail common assumptions for approximately thirty prescriptive residential and commercial/industrial electric energy efficiency measures savings. For each measure, the TRM includes either specific deemed values or algorithms[1] for calculating:

- Gross annual electric energy savings;
- Gross electric summer coincident peak demand savings;
- Gross annual fossil fuel energy savings (for electric efficiency measures that also save fossil fuels, and for certain measures that can save electricity or fossil fuels);
- Other resource savings if appropriate (e.g. water savings, O&M impacts);
- Incremental costs; and
- Measure lives.

The TRM is intended to be easy to use and to serve a wide range of important users and functions, including:

- **Utilities and efficiency Program Administrators** - for cost-effectiveness screening and program planning, tracking, and reporting.
- **Regulatory entities, independent program evaluators, and other parties** - for evaluating the performance of efficiency programs relative to statutory goals and facilitating planning and portfolio review; and
- **Markets, such as PJM's Reliability Pricing Model (its wholesale capacity market) and future carbon markets** - for valuing efficiency resources.

The TRM is intended to be a flexible and living document. To that end, NEEP, the project sponsors and the TRM authors all expect it to be periodically updated with additional measures, modifications to characterizations of existing measures and even removal of some measures when they are no longer relevant to regional efficiency programs. Initial recommendations for a process by which updates could occur are provided in Appendix B.

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[1] Typically, the algorithms provided contain a number of deemed underlying assumptions which when combined with some measure specific information (e.g. equipment capacity) produce deemed calculated savings values.

Context

The Forum initiated this project as a benefit to both the Mid-Atlantic States and the overall Forum Region, for the following reasons:

- To improve the credibility and comparability of energy efficiency resources to support state and regional energy, climate change and other environmental policy goals;
- To remove barriers to the participation of energy efficiency resources in regional markets by making EM&V practices and savings assumptions more transparent, understandable and accessible;
- To reduce the cost of EM&V activities by leveraging resources across the region for studies of common interest (where a need for such studies has been identified); and
- To inform the potential development of national EM&V protocols.

This is the first generation of a document of this type that has been prepared for the mid-Atlantic sponsors, and one of few in the country to serve a multi-jurisdictional audience. For definitions of many energy efficiency terms and acronyms included in the TRM, users of this TRM may want to refer to the EMV Forum Glossary available at: http://neep.org/emv-forum/forum-products-and-guidelines. It is important to note that because the TRM was developed on a parallel schedule with the EMV Forum Product A2 (Common Methods Project), draft A2 materials contributed to the research for the TRM, for measures which were common to both Forum projects (specifically residential and commercial lighting measures, residential central and commercial unitary air conditioning, and variable frequency drives).

It is also recognized that programs throughout the Mid-Atlantic region are in the early stages of implementation of efficiency programs and only just beginning to conduct significant new market research and evaluation studies. As a result, there were less local data upon which to rely than is the case in some other regions of the country. It will be important to update the TRM as efficiency programs mature and more evaluation data becomes available. In addition, efficiency programs in the region are not identical and either the availability or the results of existing baseline studies and other sources of information can differ across organizations and jurisdictions. Also, different budgets and policy objectives exist, and states may have different EM&V requirements and practices. Given these considerations, the contents of this TRM reflect the consensus agreement and best judgment of project sponsors, managers, and consultants on information that was most useful and appropriate to include within the time, resource, and information constraints of the study.

Approach

This section briefly identifies and describes the process used to develop the TRM. In addition, it provides an overview of some of the considerations and decisions involved in the development of estimates for the many parameters. The development of this TRM required a balance of effectiveness, functionality, and relevance with available sources and research costs. It is helpful to keep in mind that each measure characterization has numerous components, including baseline consumption, annual energy savings, coincident peak demand savings, useful life, and incremental cost. Many of those components have a number of sub-components. Thus, the project needed to research and develop literally hundreds of unique assumptions. It is further helpful to keep in mind that because the project served a multijurisdictional audience, it required data requests, review, and consensus decision-making by a subcommittee comprised of project sponsors (see the end of this Introduction for a list of subcommittee members). The subcommittee was responsible for review and approval of the products generated in each of the tasks needed to complete the project.

Development of the TRM consisted of the following tasks:

Task 1: Prioritization/Measure Selection.
By design, this TRM was restricted to thirty priority prescriptive measures, due to a combination of project resource constraints and the recognition that typically 10 - 20% of a portfolio of efficiency measures (such as CFLs, T8s or super-T8s, some cooling measures, efficient water heaters) likely account for the large majority (90% or more) of future savings claims from prescriptive measures (i.e., those measures effectively characterized by deemed savings).

Measures were selected on the basis of projected or expected savings from program data by measure type provided by Baltimore Gas and Electric, expert judgment, and review of other relevant criteria available from regulatory filings and the region's Program Administrators. The final list of measures included those likely to provide a significant contribution to the portfolios of sponsors' efficiency programs, plus some, such as heat pump water heaters, that are expected to increase in importance. Note that some of the thirty measures chosen were variations on other measures (e.g. two different efficiency tiers for room air conditioners). Because gas measures were not common to all sponsors, these were eliminated from the list of priority measures, but there is consensus that gas measures should be included in a future update. However for those measures where fossil fuel savings occur in addition to electricity savings (for example the clothes washer measure), or where either electric or fossil fuel savings could be realized depending on the heating fuel used (for example domestic hot water conservation measures), appropriate MMBtu savings have been provided.

Task 2: Development of Deemed Impacts.

Development of the contents of the TRM proceeded in two stages. The first stage was research, analysis, and critical review of available information to inform the range of assumptions considered for each parameter and each measure included in the TRM. This was based on a comparative study of many secondary sources including existing TRMs for New Jersey, New York, Connecticut, Massachusetts and Vermont as well, as mentioned earlier, as some information that was developed for the EMV Forum Product "A2" (Common Methods Project).

The comparative analysis itself was not always as straightforward as it might initially seem because the measures included in different jurisdictions' TRMs are sometimes a little different from each other - in efficiency levels promoted, capacity levels considered, the design of program mechanisms for promoting the measures and various other factors. In addition, such variables may be different in the mid-Atlantic region than in other jurisdictions. Thus, the comparative analysis of many assumptions required calibration to common underlying assumptions. Wherever possible, such underlying assumptions - particularly for region-specific issues such as climate, codes and key baseline issues - were derived from the mid-Atlantic region. In the end, the comparative analysis documented the range of assumptions used in other jurisdictions for each key measure parameter, the average value for those jurisdictions and the reasons for the differences.

The second stage was development of specific recommendations for assumptions or assumption algorithms (informed by the comparative analysis), along with rationales and references for the recommendations. These recommended assumptions identified cases where calculation of savings is required and where options exist (for example two coincidence factor values are provided for central AC measures, based on two definitions of peak coincidence factors) for calculation of impact. They also recommend deemed values where consistency can or should be achieved. The following criteria were used in the process of reviewing the proposed assumptions and establishing consensus on the final contents of the TRM:

- **Credibility.** The savings estimates and any related estimates of the cost-effectiveness of efficiency investments are credible.
- **Accuracy and completeness.** The individual assumptions or calculation protocols are accurate, and measure characterizations capture the full range of effects on savings.
- **Transparency.** The assumptions are considered by a variety of stakeholders to be transparent - that is, widely-known, widely accessible, and developed and refined through an open process that encourages and addresses challenges from a variety of stakeholders.
- **Cost efficiency.** The contents of the TRM addressed all inputs that were well within the established project scope and constraints. Sponsors recognize that there are improvements and additions that can be made in future generations of this document.

Additional notes regarding the high level rationale for extrapolation for Mid-Atlantic estimates from the Northeast and other places are provided below under Intended Uses of the TRM.

Task 3: Development of Recommendations for Update.

The purpose of this task was to develop a recommended process for when and how information will be incorporated into the TRM in the future. This task assumes that the process of updating and maintaining the TRM is related to but distinct from processes for verification of annual savings claims by Program Administrators. It further assumes that verification remains the responsibility of individual organizations unlike the multi-sponsor, multi-jurisdictional TRM. The development of these recommendations was based on the following considerations:

- Review processes in other jurisdictions. This included New Jersey, Ontario, Vermont, and Ohio.

- Expected uses of the TRM. This assumes that the TRM will be used to conduct prospective cost-effectiveness screening of utility programs, to estimate progress towards goals and potentially to support bidding into capacity markets. Note that both the contents of the document and the process and timeline by which it is updated might need to be updated to conform to the standards PJM requires, once sponsors have gained additional experience with the capacity market.

- Expected timelines required to implement the TRM protocols.

- Processes stakeholders envision for conducting annual reviews of utility program savings as well as program evaluations, and therefore what time frame for TRM updates can accommodate these.

- Feasibility of merging or coordinating the Mid-Atlantic protocols with those of other States, such as Pennsylvania, New Jersey or entire the Northeast.

Task 4: Delivery of Draft and Final Product.

The final content of the TRM reflects the consensus approval of the results from Task 2 as modified following a peer review. By design, the final version of the TRM document is similar to other TRMs currently available, for ease of comparison and update and potential merging with others in the future.

Use of the TRM

As noted above, The TRM is intended to serve as an important tool to support rate-funded efficiency investments, both for planning and assessment of success in meeting specific state goals. In addition, the TRM is intended to support the bidding of efficiency resources into capacity markets, such as PJM's Reliability Pricing Model and in setting and tracking future environmental and climate change goals. It provides a common platform for the Mid-Atlantic stakeholders to characterize measures within their efficiency programs, analyze and meaningfully compare cost-effectiveness of measures and programs, communicate with policymakers about program details, and it can guide future evaluation and measurement activity and help identify priorities for investment in further study, needed either at a regional or individual organizational level.

The savings estimates are expected to serve as representative, recommended values, or ways to calculate savings based on program-specific information. All information is presented on a per measure basis. In using the measure-specific information in the TRM, it is helpful to keep the following notes in mind:

- The TRM clearly identifies whether the measure impacts pertain to "retrofit", "time of sale",[2] or "early retirement" program designs.

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[2] In some jurisdictions, this is called "replace on burn-out". We use the term "time of sale" because not all new equipment purchases take place when an older existing piece of equipment reaches the end of its life.

- Additional information about the program design is sometimes included in the measure description because program design can affect savings and other parameters.
- Savings algorithms are typically provided for each measure. For a number of measures, prescriptive values for each of the variables in the algorithm are provided along with the output from the algorithm. That output is the deemed assumption. For other measures, prescriptive values are provided for only some of the variables in the algorithm, with the term "actual" or "actual installed" provided for the others. In those cases - which one might call "deemed calculations" rather than "deemed assumptions" - users of the TRM are expected to use actual efficiency program data (e.g. capacities or rated efficiencies of central air conditioners) in the formula to compute savings. Note that the TRM typically provides *example calculations* for measures requiring "actual" values. These are for illustrative purposes only.
- All estimates of savings are annual savings and are assumed to be realized for each year of the measure life (unless otherwise noted).
- Unless otherwise noted, measure life is defined to be "The life of an energy consuming measure, including its equipment life and measure persistence (not savings persistence)" (EMV Forum Glossary). Conceptually it is similar to expected useful life, but the results are not necessarily derived from modeling studies, and many are from a report completed for New England program administrators' and regulators' State Program Working Group that is currently used to support the New England Forward Capacity Market M&V plans.
- Where deemed values for savings are provided, these represent average savings that could be expected from the average measures that might be installed in the region in 2011.
- For measures that are not weather-sensitive, peak savings are estimated whenever possible as the average of savings between 2 pm and 6 pm across all summer weekdays (i.e. PJM's EE Performance Hours for its Reliability Pricing Model). Where possible for cooling measures, we provide estimates of peak savings in two different ways. The primary way is to estimate peak savings during the most typical peak hour (assumed here to be 5 p.m.) on days during which system peak demand typically occurs (i.e., the hottest summer weekdays). This is most indicative of actual peak benefits. The secondary way - typically provided in a footnote - is to estimate peak savings as it is measured for non-cooling measures: the average between 2 pm and 6 pm across <u>all</u> summer weekdays (regardless of temperature). The second way is presented so that values can be bid into the PJM RPM.
- Wherever possible, savings estimates and other assumptions are based on mid-Atlantic data. For example, data from a BG&E metering study of residential central air conditioners was used to estimate both full load hours and system peak coincidence factors. However, a number of assumptions - including assumptions regarding peak coincidence factors - are based on New York and/or New England sources. While this information is not perfectly transferable, due to differences in definitions of peak periods as well as

geography and climate and customer mix, it was used because it was the most transferable and usable source available at the time.[3]

- Users will note that the TRM presents engineering equations for most measures. These were judged to be desirable because they convey information clearly and transparently, and they are widely accepted in the industry. Unlike simulation model results, they also provide flexibility and opportunity for users to substitute locally specific information and to update some or all parameters as they become available on an ad hoc basis. One limitation is that certain interaction effects between end uses, such as how reductions in waste heat from many efficiency measures impacts space conditioning, are not universally captured in this version of the TRM.[4]
- For some of the whole-building program designs that are being planned or implemented in the Mid-Atlantic, simulation modeling may be needed to estimate savings. While they were beyond the scope of this TRM, it is recommended that a future version of the TRM may include the baseline specifications for any whole-building efficiency measures.
- In general, the baselines included in the TRM are intended to represent average conditions in the Mid-Atlantic. Some are based on data from the Mid-Atlantic, such as household consumption characteristics provided by the Energy Information Administration. Some are extrapolated from other areas, when Mid-Atlantic data are not available.
- When weather adjustments were needed in extrapolations, Baltimore weather conditions were generally used as a proxy for the region. This decision was made after comparing Baltimore, MD, Washington, D.C., Dover, DE and other temperature and humidity indicators.
- The TRM anticipates the effects of changes in efficiency standards for some measures, specifically CFLs and motors.

Going forward, the project sponsors can use this TRM, along with other Forum products on common EM&V terminology, guidelines on common evaluation methods, and common reporting formats, along with the experience gained from implementation of the efficiency programs to inform decisions about what savings assumptions should be updated and how. Future TRM updates may also expand the parameters, measures or programs covered beyond those currently included.

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[3] For more discussion about the transferability of consumption data, see the EMV Forum Report: Cataloguing Available End-Use and Efficiency Measure Load Data, October 2009 at http://neep.org/emv-forum/forum-products-and-guidelines.

[4] They are captured only for lighting measures.

TRM Update History

Version	Issued
1.1	October 2010
1.2	March 2011
2.0	July 2011

RESIDENTIAL MARKET SECTOR

Lighting End Use

CFL Screw base, Retail - Residential

Unique Measure Code(s): RS_LT_TOS_CFLSCR_V1.0510

Effective Date: March 2011
End Date: December 31, 2011

Measure Description

A compact fluorescent light bulb (CFL) is purchased in retail and installed in a residential location. The incremental cost of the CFL compared to an incandescent light bulb is offset via either rebate coupons or via upstream markdowns. Assumptions are based on a time of sale purchase, not as a retrofit or direct install installation. Also, this characterization is for a general purpose screw based CFL bulb, and not a specialty bulb.

Definition of Baseline Condition

The baseline is the purchase and installation of a standard incandescent light bulb.

Definition of Efficient Condition

The efficient condition is the purchase and installation of a compact fluorescent light bulb.

Annual Energy Savings Algorithm

$$\Delta kWh = ((\Delta Watts)/1000) * ISR * HOURS * WHFe$$

Where:

ΔWatts = Compact Fluorescent Watts (if known) * 2.95[5]

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from

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[5] Average wattage of compact fluorescent from RLW study was 15.5W, and the replacement incandescent bulb was 61.2W. This is a ratio of 3.95 to 1, and the delta watts is equal to the compact fluorescent bulb multiplied by 2.95:
RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

the Energy Independence and Security Act of 2007 discussed below:

CFL Wattage	Delta Watts Multiplier[6]			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	2.95	2.95	2.95	1.83
16-20	2.95	2.95	1.79	1.79
21W+	2.95	1.84	1.84	1.84

If Compact Fluorescent Watts is unknown use 45.7 [7]

Note: The delta watts should be adjusted to 28.2[8] from 2013 onwards to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below.

ISR = *In Service Rate or percentage of units rebated that get installed.*
= *0.88* [9]

HOURS = *Average hours of use per year*
= *1088 (2.98 hrs per day)* [10]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
= *1.14* [11]

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[6] Calculated by finding the new delta watts after incandescent bulb wattage is reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014); see MidAtlantic CFL Adjustments.xls.

[7] RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

[8] Calculated by multiplying 45.7 by the average adjustment 2014 percentage adjustment from table below. This adjustment should be made in 2013 since this is the midpoint of the 3 EISA adjustment years.

[9] Starting with a first year ISR of 0.81 (based on EmPOWER Maryland DRAFT 2010 Interim Evaluation Report; Chapter 5: Lighting and Appliances) and a lifetime ISR of 0.97 (from Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009"), and assuming 43% of the remaining 16% not installed in the first year replace incandescents (24 out of 56 respondents not purchased as spares; Nexus Market Research, RLW Analytics, October 2004; "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs", table 6-7). ISR is therefore calculated as 0.81 + (0.43*0.16) = 0.88. See MidAtlantic CFL Adjustments.xls for calculation.

[10] Based on EmPOWER Maryland DRAFT 2010 Interim Evaluation Report; Chapter 5: Lighting and Appliances.

[11] Waste heat factor for energy to account for cooling savings from efficient lighting. The value is estimated at 1.14 (calculated as 1 + (0.78*(0.45) / 2.5)). Based on 0.45 ASHRAE

For example:

$$\Delta kWh = ((45.7)/1000) * 0.88 * 1088 * 1.14$$

$$= 49.9 \text{ kWh}$$

Baseline Adjustment[12]

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[13]:

CFL Wattage	Savings as Percentage of Base Year Savings			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	100%	100%	100%	62%
16-20	100%	100%	61%	61%
21W+	100%	63%	63%	63%

Lighting waste heat cooling factor for Washington DC (http://lighting.bki.com/pubs/b6_tab1.htm) and assuming typical cooling system operating efficiency of 2.5 COP (accounting for distribution losses, inadequate airflow etc). Assuming 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[12] Note that the EISA adjustments discussed only apply to general purpose CFL bulbs. Specialty bulbs (not characterized here) are not currently subject to these adjustments.

[13] Calculated by finding the percentage reduction in delta watts, for example for a 100W bulb: (72-25.3)/(100-25.3) = 62.5%. See MidAtlantic CFL Adjustments.xls for calculation.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\Delta Watts) / 1000) * ISR * WHFd * CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.39* [14]

CF = *Summer Peak Coincidence Factor for measure*
= *0.11* [15]

For example:

$$\Delta kW = ((45.7) / 1000) * 0.88 * 1.39 * 0.11$$

$$= 0.0061 \text{ kW}$$

Note: The savings adjustment due to the shifting baseline documented above should be applied to the peak kW savings assumed in the later years.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $3.[16]

Measure Life

The measure life is assumed to be 5.7 years.[17]

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[14] Waste heat factor for demand to account for cooling savings from efficient lighting. The value is estimated at 1.39 (calculated as 1 + (0.78 / 2.0)). Based on 2.0 COP cooling system efficiency during peak hours, and 78% of homes having central cooling (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[15] RESIDENTIAL LIGHTING MARKDOWN IMPACT EVALUATION, FINAL, January 20, 2009, Submitted to: Markdown and Buydown Program Sponsors in Connecticut, Massachusetts, Rhode Island, and Vermont. Submitted by: Nexus Market Research, Inc., RLW Analytics, Inc.

[16] Based on review of TRM assumptions for other States.

[17] Calculated starting with an average observed life (5.2 years) of compact fluorescent bulbs with rated life of 8000 hours (8000 hours is the average rated life of ENERGY STAR bulbs (http://www.energystar.gov/index.cfm?c=cfls.pr_crit_cfls)). Observed life is based on Jump

Operation and Maintenance Impacts

In order to account for the shift in baseline due to the Federal Legislation discussed above, the levelized baseline replacement cost over the lifetime of the CFL is calculated (see MidAtlantic CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

	Standard Incandescent	Efficient Incandescent
Replacement Cost	$0.50	$2.00
Component Life (years) (based on lamp life / assumed annual run hours)	1[18]	3[19]

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below:

CFL wattage	NPV of baseline Replacement Costs[20]				
	2010	2011	2012	2013	2014 on
21W+	$4.59	$4.37	$2.98	$2.98	$2.98
16-20W	$3.65	$4.59	$4.37	$2.98	$2.98
15W and less	$3.90	$3.65	$3.39	$3.12	$2.98

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et al “Welcome to the Dark Side: The Effect of Switching on CFL Measure Life” and is due to increased on/off switching. The 5.2 years is adjusted upwards due to the assumption that 57% of the 16% not installed in the first year eventually replace CFLs (based on 32 out of 56 respondents purchased as spares; Nexus Market Research, RLW Analytics, October 2004; “Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs”, table 6-4). Measure life is therefore calculated as (5.2 + (((0.57 * 0.16)/0.88) *5.2) = 5.7 years.
Note, a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore after 2014 the measure life will have to be reduced each year to account for the number of years remaining to 2020.[17]

[18] Assumes rated life of incandescent bulb of 1000 hours.

[19] VEIC best estimate of future technology.

[20] Note, these values have been adjusted by the appropriate In Service Rate.

Hardwired CFL Fixtures (Interior)

Unique Measure Code(s): RS_LT_RTR_CFLFIN_V1.0510 and RS_LT_INS_CFLIN_V1.0510

Effective Date: March 2011
End Date:

Measure Description

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an interior residential setting. This measure could relate to either retrofit or new installation.

Definition of Baseline Condition

The baseline condition is a standard incandescent interior fixture.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR lighting interior fixture for pin-based compact fluorescent lamps.

Annual Energy Savings Algorithm

$$\Delta kWh = ((\Delta Watts) / 1000) * ISR * HOURS * WHFe$$

Where:

ΔWatts = *Compact Fluorescent Watts (if known) * 2.95* [21]

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below:

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[21] This is the same ratio as the CFL bulb, and is used for fixtures in the absence of better data since the Nexus Market Research study only provided delta watts and did not specify incandescent or CFL fixture wattages. Average wattage of compact fluorescent from RLW study was 15.5W, and the replacement incandescent bulb was 61.2W. This is a ratio of 3.95 to 1, and the delta watts is equal to the compact fluorescent bulb multiplied by 2.95: RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

CFL Wattage	Delta Watts Multiplier[22]			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	2.95	2.95	2.95	1.83
16-20	2.95	2.95	1.79	1.79
21W+	2.95	1.84	1.84	1.84

If Compact Fluorescent Watts is unknown use = 48.7 [23]

Note: The delta watts should be adjusted to 30.1[24] from 2013 onwards to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below.

ISR = *In Service Rate or percentage of units rebated that get installed. =0.95* [25]

HOURS = *Average hours of use per year*
= *1088 (2.98 hrs per day)* [26]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
= *1.14* [27]

For example:

ΔkWh = ((48.7) / 1000) * 0.95 * 1088 * 1.14

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[22] Calculated by finding the new delta watts after incandescent bulb wattage is reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014). See MidAtlantic CFL Adjustments.xls for calculation.

[23] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 43 (Table 4-9). This value for delta watts is per fixture, not per lamp.

[24] Calculated by multiplying 48.7 by the average adjustment 2014 percentage adjustment from table below. This adjustment should be made in 2013 since this is the midpoint of the 3 EISA adjustment years.

[25] Consistent with Efficiency Vermont and CT Energy Efficiency Fund; based on Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 42 (Table 4-7).

[26] Based on EmPOWER Maryland DRAFT 2010 Interim Evaluation Report; Chapter 5: Lighting and Appliances. This study is based on both lamp and fixture lighting logger results.

[27] Waste heat factor for energy to account for cooling savings from efficient lighting. The value is estimated at 1.14 (calculated as 1 + (0.78*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC. (http://lighting.bki.com/pubs/b6_tab1.htm) and assuming typical cooling system operating efficiency of 2.5 COP (accounting for distribution losses, inadequate airflow etc). Assuming 7834% of homes have central cooling (based on BGE 2005 Residential Appliance Saturation Survey (RASS)).

= 57 kWh

Baseline Adjustment

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[28]:

CFL Wattage	Savings as Percentage of Base Year Savings			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	100%	100%	100%	62%
16-20	100%	100%	61%	61%
21W+	100%	63%	63%	63%

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\Delta Watts)/1000) * ISR * WHFd * CF$$

Where:

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[28] Calculated by finding the percentage reduction in delta watts, for example for a 100W bulb: (72-25.3)/(100-25.3) = 62.5%. See MidAtlantic CFL Adjustments.xls for calculation.

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.39* [29]

CF = *Summer Peak Coincidence Factor for measure*
= *0.11* [30]

For example:

$$\Delta kW = (48.7 / 1000) * 0.95 * 1.39 * 0.11$$

$$= 0.007 \text{ kW}$$

Note: The savings adjustment due to the shifting baseline documented above should be applied to the peak kW savings assumed in the later years.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for an interior fixture is assumed to be $15.[31]

Measure Life

An additional provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline.

The measure life of an interior fixture[32] will therefore need to be reduced each year and be equal to the remaining number of years before 2020, i.e. for installations in 2010 the measure life should be 10 years, for installations in 2011 the measure life should be 9 years etc.

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[29] Waste heat factor for demand to account for cooling savings from efficient lighting. The value is estimated at 1.39 (calculated as 1 + (0.78 / 2.0)). Based on 2.0 COP cooling system efficiency during peak hours, and 78% of homes having central cooling (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[30] RESIDENTIAL LIGHTING MARKDOWN IMPACT EVALUATION, FINAL, January 20, 2009, Submitted to: Markdown and Buydown Program Sponsors in Connecticut, Massachusetts, Rhode Island, and Vermont. Submitted by: Nexus Market Research, Inc., RLW Analytics, Inc.

[31] Estimate based on review of TRM assumptions from other States.

[32] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf) gives 20 years for an interior fluorescent fixture.

Operation and Maintenance Impacts

In order to account for the shift in baseline due to the Federal Legislation discussed above, the levelized baseline replacement cost over the lifetime of the CFL is calculated (see MidAtlantic CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

	Baseline		Efficient
	Standard Incandescent	Efficient Incandescent	CFL
Replacement Cost	$0.50	$2.00	$3.50
Component Life (years) (based on lamp life / assumed annual run hours)	1[33]	3[34]	8

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below:

CFL wattage	NPV of baseline Replacement Costs[35]				
	2010	2011	2012	2013	2014 on
21W+	$2.70	$2.47	$3.21	$3.21	$3.21
16-20W	$1.69	$2.70	$4.72	$3.21	$3.21
15W and less	$1.96	$1.69	$3.66	$3.37	$3.21

---

[33] Assumes rated life of incandescent bulb of 1000 hours (simplified to 1 year for calculation).

[34] VEIC best estimate of future technology.

[35] Note, these values have been adjusted by the appropriate In Service Rate.

Hardwired CFL Fixtures (Exterior)

Unique Measure Code(s): RS_LT_RTR_CFLFEX_V1.0510 and RS_LT_INS_CFLFEX_V1.0510
Effective Date: May 2010
End Date:

Measure Description

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an exterior residential setting. This measure could relate to either retrofit or new installation.

Definition of Baseline Condition

The baseline condition is a standard incandescent exterior fixture.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR lighting exterior fixture for pin-based compact fluorescent lamps.

Annual Energy Savings Algorithm

$$\Delta kWh = ((\Delta Watts) / 1000) * ISR * HOURS$$

Where:

ΔWatts = *Compact Fluorescent Watts (if known)* * 2.95 [36]

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below:

---

[36] This is the same ratio as the CFL bulb, and is used for fixtures in the absence of better data since the Nexus Market Research study only provided delta watts and did not specify incandescent or CFL fixture wattages. Average wattage of compact fluorescent from RLW study was 15.5W, and the replacement incandescent bulb was 61.2W. This is a ratio of 3.95 to 1, and the delta watts is equal to the compact fluorescent bulb multiplied by 2.95:
RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

CFL Wattage	Delta Watts Multiplier[37]			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	2.95	2.95	2.95	1.83
16-20	2.95	2.95	1.79	1.79
21W+	2.95	1.84	1.84	1.84

If Compact Fluorescent Watts is unknown use 94.7 [38]

Note: The delta watts should be adjusted to 58.5[39] from 2013 onwards to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below.

ISR = *In Service Rate or percentage of units rebated that get installed*
= *0.87* [40]
HOURS = *Average hours of use per year*
= *1643 (4.5 hrs per day)*[41]

For example:

$$\Delta kWh = ((94.7) / 1000) * 0.87 * 1643$$

$$= 135 \text{ kWh}$$

Baseline Adjustment

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and

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[37] Calculated by finding the new delta watts after incandescent bulb wattage is reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014). See MidAtlantic CFL Adjustments.xls for calculation.

[38] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 43 (Table 4-9). This value for delta watts is per fixture, not per lamp.

[39] Calculated by multiplying 94.7 by the average adjustment 2014 percentage adjustment from table below. This adjustment should be made in 2013 since this is the midpoint of the 3 EISA adjustment years.

[40] Consistent with Efficiency Vermont and CT Energy Efficiency Fund; based on Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 42 (Table 4-7).

[41] Updated results from above study, presented in 2005 memo; http://publicservice.vermont.gov/energy/ee_files/efficiency/eval/marivtfinalresultsmemodelivered.pdf

100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[42]:

CFL Wattage	Savings as Percentage of Base Year Savings			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	100%	100%	100%	62%
16-20	100%	100%	61%	61%
21W+	100%	63%	63%	63%

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\Delta Watts) / 1000) * ISR * CF$$

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *0.018* [43]

For example:

$$\Delta kW = (94.7 / 1000) * 0.87 * 0.018$$

---

[42] Calculated by finding the percentage reduction in delta watts, for example for a 100W bulb: (72-25.3)/(100-25.3) = 62.5%. See MidAtlantic CFL Adjustments.xls for calculation.

[43] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

= 0.0015 kW

Note: The savings adjustment due to the shifting baseline documented above should be applied to the peak kW savings assumed in the later years.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for an exterior fixture is assumed to be $20.[44]

Measure Life

An additional provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline.

The measure life of an exterior fixture[45] will therefore need to be reduced each year and be equal to the remaining number of years before 2020, i.e. for installations in 2010 the measure life should be 10 years, for installations in 2011 the measure life should be 9 years etc.

Operation and Maintenance Impacts

In order to account for the shift in baseline due to the Federal Legislation discussed above, the levelized baseline replacement cost over the lifetime of the CFL is calculated (see MidAtlantic CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

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[44] Estimate based on review of TRM assumptions from other States.

[45] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf) gives 15 years for an exterior fluorescent fixture.

	Baseline		Efficient
	Standard Incandescent	Efficient Incandescent	CFL
Replacement Cost	$0.50	$2.00	$3.50
Component Life (years) (based on lamp life / assumed annual run hours)	0.5[46]	2.0[47]	5[48]

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below:

CFL wattage	NPV of baseline Replacement Costs[49]				
	2010	2011	2012	2013	2014 on
21W+	$4.36	$3.81	$1.92	$1.92	$1.92
16-20W	$3.77	$4.36	$3.81	$1.92	$1.92
15W and less	$4.33	$3.77	$3.19	$2.57	$1.92

---

[46] Assumes rated life of incandescent bulb of 1000 hours (simplified to 0.5 for calculation).
[47] VEIC best estimate of future technology.
[48] Assumes rated life of 8000 hours (simplified to 5 years for calculation).
[49] Note, these values have been adjusted by the appropriate In Service Rate.

Solid State Lighting (LED) Recessed Downlight Lamp

Unique Measure Code: RS_LT_TOS_SSLDWN_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes savings from the purchase and installation of a Solid State Lighting (LED) Recessed Downlight lamp in place of an incandescent downlight lamp (i.e. time of sale). The SSL downlight should meet the ENERGY STAR Specification for Solid State Luminaires[50]. The characterization of this measure should not be applied to other types of LEDs.

Note, this measure assumes the baseline is a Bulged Reflector (BR) lamp. This lamp type is generally the cheapest and holds by far the largest market share for this fixture type. They currently are *not* subject to EISA regulations and so this characterization does not include the baseline shift provided in other lighting measures.

Definition of Baseline Condition

The baseline is the purchase and installation of a standard BR-type incandescent downlight light bulb.

Definition of Efficient Condition

The efficient condition is the purchase and installation of a Solid State Lighting (LED) Recessed Downlight light bulb.

Annual Energy Savings Algorithm

$$\Delta kWh = ((BaseWatts - EffWatts) / 1{,}000) * ISR * HOURS * WHFe$$

Where:

BaseWatts = *Connected load of baseline lamp*

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[50] ENERGY STAR specification can be viewed here: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/SSL_FinalCriteria.pdf

= 65W [51]

EffWatts = Connected load of efficient lamp
= 12W [52]

ISR = In Service Rate or percentage of units rebated that get installed.
= 0.95 [53]

HOURS = Average hours of use per year
= 1241 (3.4 hrs per day)[54]

WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.
= 1.14 [55]

$$\Delta kWh = ((65-12) / 1{,}000) * 0.95 * 1241 * 1.14$$

$$= 71 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((BaseWatts - EffWatts) / 1000) * ISR * WHFd * CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting
= 1.39 [56]

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[51] Baseline wattage based on common 65 Watt BR30 incandescent bulb (e.g. http://www.destinationlighting.com/storeitem.jhtml?iid=16926)

[52] Energy Efficient wattage based on 12 Watt LR6 Downlight from LLF Inc. (http://site4.marketsmartinteractive.com/products.htm)

[53] VEIC estimate. Assumed higher than CFL because significantly higher cost.

[54] There is an absence of evaluations that have looked at SSL lamp run hours so the estimate provided is based on professional judgment. The assumption is that the installation of a more expensive LED downlight will be in a high use location. Therefore assume CFL run hour finding from 12 years ago, when the same was true of CFLs; 3.4 hours based on Xenergy 1998 study "Process and Impact Evaluation of Joint Utilities Starlights Residential Lighting Program".

[55] Waste heat factor for energy to account for cooling savings from efficient lighting. The value is estimated at 1.14 (calculated as 1 + (0.78*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC (http://lighting.bki.com/pubs/b6_tab1.htm) and assuming typical cooling system operating efficiency of 2.5 COP (accounting for distribution losses, inadequate airflow etc). Assuming 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[56] Waste heat factor for demand to account for cooling savings from efficient lighting. The value is estimated at 1.39 (calculated as 1 + (0.78 / 2.0)). Based on 2.0 COP cooling system

CF = *Summer Peak Coincidence Factor for measure*
= *0.11* [57]

$$\Delta kW = ((65 - 12) / 1{,}000) * 0.95 * 1.39 * 0.11$$

$$= 0.0077 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $61[58].

Measure Life

The measure life is assumed to be 20 yrs[59].

Operation and Maintenance Impacts

The levelized baseline replacement cost over the lifetime of the SSL is calculated (see MidAtlantic CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

	BR-type Incandescent
Replacement Cost	$4.00
Component Life (years) (based on lamp life / assumed annual run hours)	1.6[60]

The calculated net present value of the baseline replacement costs is $30.85.

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efficiency during peak hours, and 78% of homes having central cooling (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[57] RESIDENTIAL LIGHTING MARKDOWN IMPACT EVALUATION, FINAL, January 20, 2009, Submitted to: Markdown and Buydown Program Sponsors in Connecticut, Massachusetts, Rhode Island, and Vermont. Submitted by: Nexus Market Research, Inc., RLW Analytics, Inc.

[58] Based on VEIC product review, April 2011. Baseline bulbs available in $3-$5 range, and SSL bulbs available in $50-$80 range. Incremental cost of $61 therefore assumed ($4 for the baseline bulb and $65 for the SSL). Note, this product is likely to fall rapidly in cost, so this should be reviewed frequently.

[59] The ENERGY STAR Spec for SSL Recessed Downlights requires luminaires to maintain >=70% initial light output for 25,000 hrs in a residential application. Measure life is therefore assumed to be 20 yrs (25000/1241); http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/SSL_FinalCriteria.pdf

[60] Assumes rated life of BR incandescent bulb of 2000 hours, based on product review. Lamp life is therefore 2000/1241 = 1.6years.

Refrigeration End Use

Refrigerator

Unique Measure Code(s): RS_RF_TOS_REFRIG_V10.05
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the purchase and installation of a new refrigerator meeting either ENERGY STAR or Consortium for Energy Efficiency (CEE) TIER 2 specifications (defined as requiring >= 20% or >= 25% less energy consumption than an equivalent unit meeting federal standard requirements respectively). This is a time of sale measure characterization.

Definition of Baseline Condition

The baseline condition is a new refrigerator meeting the minimum federal efficiency standard for refrigerator efficiency.

Definition of Efficient Condition

The efficient condition is a new refrigerator meeting either the ENERGY STAR or CEE TIER 2 efficiency standards.

Annual Energy Savings Algorithm[61]

$$\Delta kWh = kWhBASE - kWhES$$

Where:

kWhBASE = *Annual energy consumption of baseline unit*
= *585.4*

kWhES = *Annual energy consumption of ENERGY STAR unit*
= *468.3*

Or = *Annual energy consumption of CEE Tier 2 unit*
= *439.1*

---

[61] kWh assumptions for base and efficient condition are based on data compiled by Efficiency Vermont that gives the average federal standard consumption for all units incentivized in their program. ENERGY STAR standards are 20% better than Federal Standard; CEE Tier 2 is 25% better.

$\Delta kWH_{ENERGY\ STAR}$

$= 585.4 - 468.3$

$= 117$ kWh

$\Delta kWH_{CEE\ TIER\ 2}$

$= 585.4 - 439.1$

$= 146$ kWh

Summary Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh/8760) * TAF * LSAF$$

Where:

TAF = Temperature Adjustment Factor

= 1.23 [62]

LSAF = Load Shape Adjustment Factor

= 1.15 [63]

$\Delta kW_{ENERGY\ STAR}$

$= (117 / 8760) * 1.23 * 1.15$

$= 0.019$ kW

$\Delta kW_{CEE\ TIER\ 2}$

$= (146 / 8760) * 1.23 * 1.15$

$= 0.024$ kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[62] Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space.

[63] Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 p. 48, (extrapolated by taking the ratio of existing summer to existing annual profile for hours ending 15 through 18, and multiplying by new annual profile).

The incremental cost for this measure is assumed to be $95 for an ENERGY STAR unit and $140 for a CEE Tier 2 unit.[64]

Measure Life

The measure life is assumed to be 17 Years.[65]

Operation and Maintenance Impacts

n/a

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[64] Based on Department of Energy, "TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers", October 2005.

[65] Consistent with Efficiency Vermont and New Jersey TRMs.

Refrigerator Early Retirement

Unique Measure Code(s): RS_RF_ERT_REFRIG_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure involves the removal of an existing inefficient refrigerator[66] from service, prior to its natural end of life (early retirement). The program should target refrigerators with an age greater than 10 years, though it is expected that the average age will be greater than 20 years based on other similar program performance. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit[67].

Definition of Baseline Condition

The existing refrigerator baseline efficiency is based upon evaluation of a number of existing programs and evaluations.

Definition of Efficient Condition

The existing inefficient refrigerator is removed from service and not replaced.

Annual Energy Savings Algorithm

$$\Delta kWh = UECretired * ISAF$$ [68]

---

[66] This measure assumes a mix of primary and secondary refrigerators will be replaced. By definition, the refrigerator in a household's kitchen that satisfies the majority of the household's demand for refrigeration is the primary refrigerator. One or more additional refrigerators in the household that satisfy supplemental needs for refrigeration are referred to as secondary refrigerators.

[67] Note that the hypothetical nature of this measure implies a significant amount of risk and uncertainty in developing the energy and demand impact estimates.

[68] There is currently no net to gross (NTG) ratio applied in this algorithm.
A NTG ratio was originally used to account for i) primary units being recycled (as opposed to secondary), ii) refrigerators only used part of the year and iii) for those that would have been removed without the program (i.e. freeriders). The new methodology addresses the first (i) and second (ii) issues because the algorithm incorporates replacement and partial-use adjustments. No other measures in the TRM include free-rider estimates at this time. The freerider adjustment has been removed to make this measure more consistent with the other measures in this TRM.

Where:

UECretired = Average in situ Unit Energy Consumption of retired unit, adjusted for part use
= 894 kWh[69]

ISAF = In Situ Adjustment Factor
= 0.85[70]

ΔkWh = 894 * 0.85

= 760 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = (ΔkWh/8760) * TAF * LSAF

Where:

TAF = Temperature Adjustment Factor
= 1.23 [71]

LSAF = Load Shape Adjustment Factor
= 1.066 [72]

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[69] Based on EmPower DRAFT 2010 Interim Evaluation Report Chapter 5: Lighting and Appliances. This suggests an average UEC of 1004kWh and an average part use factor of 0.89 to give an adjusted value of 894kWh.

[70] A recent California study suggests that in situ energy consumption of refrigerators is lower than the DOE test procedure would suggest (The Cadmus Group et al., "Residential Retrofit High Impact Measure Evaluation Report", prepared for the California Public Utilities Commission, February 8, 2010). The magnitude of the difference - estimated as 6% lower for one California utility, 11% lower for a second, and 16% lower for a third - was a function of whether the recycled appliance was a primary or secondary unit, the size of the household and climate (warmer climates show a small difference between DOE test procedure estimated consumption and actual consumption; cooler climates had lower in situ consumption levels). Ideally, such an adjustment for the Mid Atlantic should be computed using program participant data. However, in the absence of such a calculation, a 15% downward adjustment, which is near the high end of the range found in California, is assumed to be reasonable for Mid Atlantic given its cooler climate (relative to California).

[71] Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space.

[72] Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 p. 48, using the average Existing Units Summer Profile for hours ending 15 through 18.

$$\Delta kW = 760/8760 * 1.23 * 1.066$$

$$= 0.114 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure will be the actual cost associated with the removal and recyling of the secondary refrigerator.

Measure Life

The measure life is assumed to be 8 Years.[73]

Operation and Maintenance Impacts

n/a

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[73] KEMA "Residential refrigerator recycling ninth year retention study", 2004.

Heating Ventilation and Air Conditioning (HVAC) End Use

Central Furnace Efficient Fan Motor

Unique Measure Code(s): RS_HV_RTR_FANMTR_V1.0510 and RS_HV_TOS_FANMTR_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure involves the installation of a high efficiency brushless permanent magnet fan motor (BPM or ECM), hereafter referred to as "efficient fan motor". This measure could apply to fan motors installed with a furnace or with a central air conditioning unit and could apply when retrofitting an existing unit or installing a new one.

If a new unit is installed, the program should require that it meet ENERGY STAR efficiency criteria in order to qualify for the incentive, although the savings estimations below relate only to the efficiency gains associated with an upgrade to the efficient fan motor.

For homes that install an efficient furnace fan and have central A/C, both the cooling and heating savings values should be included.

Definition of Baseline Condition

A standard low-efficiency permanent split capacitor (PSC) fan motor.

Definition of Efficient Condition

A high efficiency brushless permanent magnet fan motor (BPM or ECM).

Annual Energy Savings Algorithm

Heating Season kWh Savings from efficient fan motor = 241kWh [74]

Cooling Season kWh Savings from efficient fan motor = 178kWh [75]

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[74] The average heating savings from Scott Pigg (Energy Center of Wisconsin), "Electricity Use by New Furnaces: A Wisconsin Field Study", Technical Report 230-1, October 2003, is 400kWh. An estimate for Mid-Atlantic is provided by multiplying this by the ratio of heating degree days in Baltimore MD compared to Wisconsin (4704 / 7800).

[75] The average cooling savings from Scott Pigg (Energy Center of Wisconsin), "Electricity Use by New Furnaces: A Wisconsin Field Study", Technical Report 230-1, October 2003, is 70 to 95kWh. An estimate for Mid-Atlantic is provided by multiplying by the ratio of full load cooling hours in Baltimore compared to Southern Wisconsin (1050/487). Full load hour estimates from:

Summer Coincident Peak kW Savings Algorithm

Two methodologies are provided below, the first is a deemed value to use if the appropriate sizing data is not collected, the second provides an algorithm based on the size of the cooling unit.

1. Deemed Summer Coincident Peak kW Assumption

$$\Delta kWcooling = \Delta kW * CF$$

Where:

ΔkW = *Difference in connected load kW of baseline motor and efficient fan motor*
= *0.163* [76]

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [77]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [78]

$$\Delta kWcooling_{SSP} = 0.163 * 0.69$$

$$= 0.112 \text{ kW}$$

$$\Delta kWcooling_{PJM} = 0.163 * 0.66$$

$$= 0.108 \text{ kW}$$

2. Summer Coincident Peak kW based on cooling system size

$$\Delta kWcooling = \Delta kW * CF$$

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http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls.

[76] The average delta watts power draw for a furnace with ECM compared to without is 162.5W, from Scott Pigg (Energy Center of Wisconsin), "Electricity Use by New Furnaces: A Wisconsin Field Study", Technical Report 230-1, October 2003, p34.

[77] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

[78] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the PJM Peak Definition coincidence factor is 0.66.

Where:

ΔkW = *Difference in connected load kW of baseline motor and efficient fan motor*[79]
= $(-0.023 * Tons^2) + (0.062 * Tons) + 165$

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= 0.69 [80]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= 0.66 [81]

For example, a four ton cooling unit:

$$\Delta kWcooling_{SSP} = ((-0.023 * 4^2) + (0.062 * 4) + 0.165) * 0.69$$

$$= 0.031 \text{ kW}$$

$$\Delta kWcooling_{PJM} = ((-0.023 * 4^2) + (0.062 * 4) + 0.165) * 0.66$$

$$= 0.030 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $200.[82]

Measure Life

The measure life is assumed to be 18 years.[82]

Operation and Maintenance Impacts

n/a

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[79] The polynomial algorithm is based on data pulled from the chart on p34 of Scott Pigg (Energy Center of Wisconsin), "Electricity Use by New Furnaces: A Wisconsin Field Study", Technical Report 230-1, October 2003.

[80] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

[81] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the PJM Peak Definition coincidence factor is 0.66.

[82] Sachs and Smith, April 2003; Saving Energy with Efficient Furnace Air Handlers: A Status Update and Program Recommendations.

Window A/C

Unique Measure Code(s): RS_HV_TOS_RA/CES_V1.0510 and RS_HV_TOS_RA/CT1_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the purchase (time of sale) and installation of a room air conditioning unit that meets either the ENERGY STAR or CEE TIER 1 minimum qualifying efficiency specifications presented below:

Product Class (Btu/hour)	Federal Standard (EER)	ENERGY STAR (EER)	CEE TIER 1 (EER)
8,000 to 13,999	>= 9.8	>= 10.8	>= 11.3

Definition of Baseline Condition

The baseline condition is a window AC unit that meets the current minimum federal efficiency standards presented above.

Definition of Efficient Condition

The baseline condition is a window AC unit that meets either the ENERGY STAR of CEE TIER 1 efficiency standards presented above.

Annual Energy Savings Algorithm

$$\Delta kWH = (Hours * Btu/hour * (1/EERbase - 1/EERee))/1000$$

Where:

Hours = *Run hours of Window AC unit*
= *325*[83]
Btu/hour = *Size of rebated unit*

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[83] VEIC calculated the average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) at 31%. Applying this to the FLH for Central Cooling provided for Baltimore (1050) we get 325 FLH for Room AC.

When available, the actual size of the rebated unit should be used in the calculation. In the absence of this data, the following default value can be used:

= 8500 [84]

EERbase = Efficiency of baseline unit in Btus per Watt-hour
= 9.8 [85]

EERee = Efficiency of ENERGY STAR unit in Btus per Watt-hour
= 10.8 [86]

Or = Efficiency of CEE Tier 1 unit
= 11.3 [87]

$\Delta kWH_{ENERGY\ STAR}$
$= (325 * 8500 * (1/9.8 - 1/10.8)) / 1000$
$= 26$ kWh

$\Delta kWH_{CEE\ TIER\ 1}$
$= (325 * 8500 * (1/9.8 - 1/11.3)) / 1000$
$= 37$ kWh

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = Btu/hour * (1/EERbase - 1/EERee))/1000 * CF$$

Where:

CF = Summer Peak Coincidence Factor for measure

CF_{SSP} *= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= 0.56 [88]

CF_{PJM} *= PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= 0.3 [89]

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[84] Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[85] Minimum Federal Standard for capacity range.

[86] Minimum qualifying for ENERGY STAR, or CEE Tier 1.

[87] Minimum qualifying for ENERGY STAR, or CEE Tier 1.

[88] Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008
(http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) and adjusted for the region based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps."

$\Delta kW_{ENERGY\ STAR\ SSP}$
$= (8500 * (1/9.8 - 1/10.8)) / 1000 * 0.56$
$= 0.045$ kW

$\Delta kW_{CEE\ TIER\ 1\ SSP}$
$= (8500 * (1/9.8 - 1/11.3)) / 1000 * 0.56$
$= 0.065$ kW

$\Delta kW_{ENERGY\ STAR\ PJM}$
$= (8500 * (1/9.8 - 1/10.8)) / 1000 * 0.30$
$= 0.024$ kW

$\Delta kW_{CEE\ TIER\ 1\ PJM}$
$= (8500 * (1/9.8 - 1/11.3)) / 1000 * 0.30$
$= 0.035$ kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $80 for a CEE TIER 1 unit.[90]

Measure Life

The measure life is assumed to be 12 years.[91]

Operation and Maintenance Impacts

n/a

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[90] Based on field study conducted by Efficiency Vermont.

[91] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

ENERGY STAR Central A/C

Unique Measure Code(s): RS_HV_TOS_CENA/C_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the installation of a new Central Air Conditioning ducted split system meeting ENERGY STAR efficiency standards presented below. This measure could relate to the replacing of an existing unit or the installation of a new system in an existing home (time of sale).

Efficiency Level	SEER Rating	EER Rating[92]
Federal Standard	13	11
ENERGY STAR	14.5	12

Definition of Baseline Condition

The baseline condition is a central air conditioning ducted split system that meets the minimum Federal standards.

Definition of Efficient Condition

The efficient condition is a central air conditioning ducted split system that meets the ENERGY STAR standards.

Annual Energy Savings Algorithm

$$\Delta kWH = (Hours * Btu/hour * (1/SEERbase - 1/SEERee))/1000$$

Where:

Hours = *Full load cooling hours*
Dependent on location as below:

Location	*Run Hours*
Wilmington, DE	*513*[93]

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[92] SEER and EER refer to Seasonal Energy Efficiency Ratio and Energy Efficiency Ratio, respectively.

[93] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to

Baltimore, MD	*531* [94]
Washington, DC	*668* [93]

Btu/Hour = *Size of equipment in Btu/hour (note 1 ton = 12,000Btu/hour)*
= *Actual installed*
SEERbase = *SEER Efficiency of baseline unit*
= *13* [95]
SEERee = *SEER Efficiency of ENERGY STAR unit*
= *Actual installed*

For example, a 3 ton unit with SEER rating of 14.5, in Baltimore:

$$\Delta kWH = (531 * 36000 * (1/13 - 1/14.5)) / 1000$$

$$= 152 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = Btu/hour * (1/EERbase - 1/EERee)/1000 * CF$$

Where:

EERbase = *EER Efficiency of baseline unit*
= *11* [96]
EERee = *EER Efficiency of ENERGY STAR unit*
= *Actual installed*
CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [97]
CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [98]

Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

[94] Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research.

[95] Minimum Federal Standard.

[96] Minimum Federal Standard.

[97] Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

For example, a 3 ton unit with EER rating of 12:

$$\Delta kW_{SSP} = (36000 * (1/11 - 1/12)) / 1000 * 0.69$$

$$= 0.19 \text{ kW}$$

$$\Delta kW_{PJM} = (36000 * (1/11 - 1/12)) / 1000 * 0.66$$

$$= 0.18 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided below:[99]

Efficiency Level	Cost per Ton
SEER 14	$119
SEER 15	$238
SEER 16	$357
SEER 17	$476
SEER 18	$596
SEER 19	$715
SEER 20	$834
SEER 21	$908

Measure Life

The measure life is assumed to be 18 years.[100]

Operation and Maintenance Impacts

n/a

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[98] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the PJM Peak Definition coincidence factor is 0.66.

[99] DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)

[100] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Duct Sealing

Unique Measure Code: RS_HV_RTR_DCTSLG_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure is the sealing of ducts using mastic sealant or metal tape.

Two methodologies for estimating the savings associate from sealing the ducts are provided. The first method requires the use of a blower door and the second requires careful inspection of the duct work.

1. **Modified Blower Door Subtraction** - this technique is described in detail on p44 of the Energy Conservatory Blower Door Manual; http://www.energyconservatory.com/download/bdmanual.pdf
2. **Evaluation of Distribution Efficiency** - this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table'; http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf
   a. Percentage of duct work found within the conditioned space
   b. Duct leakage evaluation
   c. Duct insulation evaluation

This is a retrofit measure.

Definition of Baseline Condition

The existing baseline condition is leaky duct work within the unconditioned space in the home.

Definition of Efficient Condition

The efficient condition is sealed duct work throughout the unconditioned space in the home.

Annual Energy Savings Algorithm

Cooling savings from reduction in Air Conditioning Load:

Methodology 1: Modified Blower Door Subtraction

a. Determine Duct Leakage rate before and after performing duct sealing:

Duct Leakage ($CFM50_{DL}$) = ($CFM50_{Whole\ House}$ - $CFM50_{Envelope\ Only}$) * SCF

Where:

$CFM50_{Whole\ House}$ = *Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential*

$CFM50_{Envelope\ Only}$ = *Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.*

SCF = *Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.*

b. Calculate duct leakage reduction, convert to $CFM25_{DL}$[101] and factor in Supply and Return Loss Factors

Duct Leakage Reduction ($\Delta CFM25_{DL}$) = (Pre $CFM50_{DL}$ - Post $CFM50_{DL}$) * 0.64 * (SLF + RLF)

Where:

SLF = *Supply Loss Factor*
= *% leaks sealed located in Supply ducts * 1*[102]
Default = 0.5[103]

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[101] 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual).

[102] Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from http://www.energyconservatory.com/download/dbmanual.pdf

RLF = *Return Loss Factor*
= *% leaks sealed located in Return ducts * 0.5*[104]
Default = 0.25[105]

c. Calculate Energy Savings:

$$\Delta kWh_{cooling} = ((\Delta CFM25_{DL}) / (Capacity * 400)) * FLHcool * BtuH) / 1000 / \eta Cool$$

Where:

$\Delta CFM25_{DL}$ = *Duct leakage reduction in CFM25*
Capacity = *Capacity of Air Cooling system (tons)*
400 = *Conversion of Capacity to CFM (400CFM / ton)*
FLHcool = *Full Load Cooling Hours*
= *Dependent on location as below:*

Location	*FLHcool*
Wilmington, DE	*513* [106]
Baltimore, MD	*531* [107]
Washington, DC	*668*

BtuH = *Size of equipment in Btuh (note 1 ton = 12,000Btuh)*
= *Actual*
$\eta Cool$ = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available use*[108]*:*

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[103] Assumes 50% of leaks are in supply ducts.

[104] Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than "average" (e.g. pulling return air from a super heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space) . More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from http://www.energyconservatory.com/download/dbmanual.pdf

[105] Assumes 50% of leaks are in return ducts.

[106] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator.
(http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

107 Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[108] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

For example, duct sealing in a house in Wilmington, DE with 3 ton, SEER 11 central air conditioning and the following blower door test results:

Before:

$CFM50_{Whole\ House}$ = 4,800 CFM50
$CFM50_{Envelope\ Only}$ = 4,500 CFM50
House to duct pressure = 45 Pascals
= 1.29 SCF (Energy Conservatory look up table)

After:

$CFM50_{Whole\ House}$ = 4,600 CFM50
$CFM50_{Envelope\ Only}$ = 4,500 CFM50
House to duct pressure = 43 Pascals
= 1.39 SCF (Energy Conservatory look up table)

Duct Leakage at CFM50:

$$CFM50_{DL\ before} = (4{,}800 - 4{,}500) * 1.29 = 387\ CFM50$$

$$CFM50_{DL\ after} = (4{,}600 - 4{,}500) * 1.39 = 139\ CFM50$$

Duct Leakage reduction at CFM25:

$$\Delta CFM25_{DL} = (387 - 139) * 0.64 * (0.5 + 0.25) = 119\ CFM25$$

Energy Savings:

$$\Delta kWh = ((119 / (3 * 400)) * 513 * 36{,}000) / 1{,}000 / 11$$

$$= 166\ kWh$$

---

system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

Heating savings for homes with electric heat (Heat Pump):

ΔkWh = ((($\Delta CFM25_{DL}$ / (Capacity * 400)) * FLHheat * BtuH) / 1,000,000 / ηHeat) * 293.1

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25
Capacity = Capacity of Air Cooling system (tons)
400 = Conversion of Capacity to CFM (400CFM / ton)
FLHheat = Full Load Heating Hours
= Dependent on location as below:

Location	FLHheat
Wilmington, DE	*1291*[109]
Baltimore, MD	*1195*[110]
Washington, DC	*1134*

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual
ηHeat = Efficiency in COP of Heating equipment
= actual. If not available use[111]*:*

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*
Heat Pump	*Before 2006*	*6.8*	*2.00*
	After 2006	*7.7*	*2.26*
Resistance	*n/a*	*n/a*	*1.00*

For example, duct sealing in a 3-ton 2.5 COP heat pump heated house in Baltimore, MD with the blower door results described above:

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[109] Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)

[110] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[111] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

ΔkWh = (((119 / (3 * 400)) * 1,195 * 36,000) / 1,000,000 / 2.5) * 293.1

= 500 kWh

Methodology 2: Evaluation of Distribution Efficiency

<u>Cooling savings from reduction in Air Conditioning Load:</u>

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute "Distribution Efficiency Look-Up Table"

$$\Delta kWh_{cooling} = ((((DE_{after} - DE_{before}) / DE_{after})) * FLHcool * BtuH) / 1,000 / \eta Cool$$

Where:

DE_{after} = *Distribution Efficiency after duct sealing*
DE_{before} = *Distribution Efficiency before duct sealing*
FLHcool = *Full Load Cooling Hours*
= *Dependent on location as below:*

Location	*FLHcool*
Wilmington, DE	*513* [112]
Baltimore, MD	*531* [113]
Washington, DC	*668*

BtuH = *Size of equipment in Btuh (note 1 ton = 12,000Btuh)*
= *Actual*
ηCool = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available use*[114]*:*

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[112] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

113 Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[114] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

For example, duct sealing in a house in Wilmington DE, with 3-ton SEER 11 central air conditioning and the following duct evaluation results:

DE_{before} = 0.80
DE_{after} = 0.90

Energy Savings:

$$\Delta kWh = ((0.90 - 0.80)/0.90) * 513 * 36{,}000) / 1{,}000 / 11$$

$$= 187 \text{ kWh}$$

Heating savings for homes with electric heat (Heat Pump of resistance):

$$kWh = (((((DE_{after} - DE_{before})/ DE_{after})) * FLHheat * BtuH) / 1{,}000{,}000 / \eta Heat) * 293.1$$

Where:

FLHheat = *Full Load Heating Hours*
= *Dependent on location as below:*

Location	FLHheat
Wilmington, DE	*1,291*[115]
Baltimore, MD	*1,195*[116]
Washington, DC	*1,134*

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[117]*:*

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[115] Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)

[116] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[117] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*
Heat Pump	*Before 2006*	*6.8*	*2.00*
	After 2006	*7.7*	*2.26*
Resistance	*n/a*	*n/a*	*1.00*

For example, duct sealing in a 2.5 COP heat pump heated house in Baltimore, MD with the following duct evaluation results:

DE_{before} = 0.80
DE_{after} = 0.90

Energy Savings:

$$\Delta kWh = ((((0.90 - 0.80)/0.90) * 1{,}195 * 36{,}000) / 1{,}000{,}000 / 2.5) * 293.1$$

$$= 560 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / FLHcool * CF$$

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [118]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [119]

---

average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[118] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

[119] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the PJM Peak Definition coincidence factor is 0.66.

Annual Fossil Fuel Savings Algorithm

<u>For homes with Fossil Fuel Heating:</u>

Methodology 1: Modified Blower Door Subtraction

$$\Delta MMBTU = (((\Delta CFM25_{DL} / (BtuH * 0.0126)) * FLHheat * BtuH) / 1{,}000{,}000 / \eta Heat$$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25
BtuH = Capacity of Heating System (Btuh)
= Actual
0.0126 = Conversion of Capacity to CFM (0.0126CFM / Btuh)[120]
FLHheat = Full Load Heating Hours
= 620[121]
$\eta Heat$ = Efficiency of Heating equipment
= Actual[122]*. If not available use 84%*[123].

For example, duct sealing in a house with a 100,000Btuh, 80% AFUE natural gas furnace and with the blower door results described above:

Energy Savings:

$$\Delta MMBTU = (((119 / (100{,}000 * 0.0126)) * 620 * 100{,}000) / 1{,}000{,}000 / 0.80$$

$$= 7.3 \text{ MMBtu}$$

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[120] Based on Natural Draft Furnaces requiring 100 CFM per 10,000 BTU, Induced Draft Furnaces requiring 130CFM per 10,000BTU and Condensing Furnaces requiring 150 CFM per 10,000 BTU (rule of thumb from http://contractingbusiness.com/enewsletters/cb_imp_43580/). Data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggested that in 2000, 32% of furnaces purchased in Maryland were condensing units. Therefore a weighted average required airflow rate is calculated assuming a 50:50 split of natural v induced draft non-condensing furnaces, as 126 per 10,000BTU or 0.0126/Btu.

[121] Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHheat assumption.

[122] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

[123] The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%.

Methodology 2: Evaluation of Distribution Efficiency

$$\Delta \text{MMBTUfossil fuel} = ((((DE_{after} - DE_{before}) / DE_{after})) * \text{FLHheat} * \text{BtuH}) / 1{,}000{,}000 / \eta\text{Heat}$$

Where:

DE_{after} = Distribution Efficiency after duct sealing
DE_{before} = Distribution Efficiency before duct sealing
FLHheat = Full Load Heating Hours
= 620[124]
BtuH = Capacity of Heating System
= Actual
ηHeat = Efficiency of Heating equipment
= Actual[125]*. If not available use 84%*[126]*.*

For example, duct sealing in a fossil fuel heated house with a 100,000Btuh, 80% AFUE natural gas furnace, with the following duct evaluation results:

DE_{before} = 0.80
DE_{after} = 0.90

Energy Savings:

$$\Delta \text{MMBTU} = ((0.90 - 0.80)/0.90) * 620 * 100{,}000) / 1{,}000{,}000 / 0.80$$

$$= 8.6 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

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[124] Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHheat assumption.

[125] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

[126] The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%.

Incremental Cost

The incremental cost for this measure should be the actual labor and material cost to seal the ducts.

Measure Life

The measure life is assumed to be 20 years[127].

Operation and Maintenance Impacts

n/a

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[127] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Air Source Heat Pump

Unique Measure Code: RS_HV_TOS_ASHP_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure relates to the installation of a new Air Source Heat Pump split system meeting ENERGY STAR efficiency standards presented below. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Efficiency Level	HSPF	SEER Rating	EER Rating[128]
Federal Standard	7.7	13	11
ENERGY STAR	8.2	14.5	12

Definition of Baseline Condition

The baseline condition is an Air Source Heat Pump split system that meets the minimum Federal standards defined above.

Definition of Efficient Condition

The efficient condition is an Air Source Heat Pump split system that meets the ENERGY STAR standards defined above.

Annual Energy Savings Algorithm

$$\Delta kWH = (FLHcool * BtuH * (1/SEERbase - 1/SEERee))/1{,}000 + (FLHheat * BtuH * (1/HSPFbase - 1/HSPFee))/1{,}000$$

Where:

FLHcool = *Full Load Cooling Hours*
= *Dependent on location as below:*

---

[128] HSPF, SEER and EER refer to Heating Seasonal Performance Factor, Seasonal Energy Efficiency Ratio and Energy Efficiency Ratio, respectively.

Location	*FLHcool*
Wilmington, DE	*513* [129]
Baltimore, MD	*531* [130]
Washington, DC	*668*

BtuH = *Capacity of Air Source Heat Pump (1 ton = 12,000Btuh)*
= *Actual*

SEERbase = *Efficiency in SEER of baseline Air Source Heat Pump*
= *13*[131]

SEERee = *Efficiency in SEER of efficient Air Source Heat Pump*
= *Actual*

FLHheat = *Full Load Heating Hours*
= *Dependent on location as below:*

Location	**FLHheat**
Wilmington, DE	*1,291*[132]
Baltimore, MD	*1,195*[133]
Washington, DC	*1,134*

HSPFbase = *Heating Seasonal Performance Factor of baseline Air Source Heat Pump*
= *7.7* [134]

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[129] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

[130] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[131] Minimum Federal Standard

[132] Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)

[133] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[134] Minimum Federal Standard

HSPFee = *Heating Seasonal Performance Factor of efficient Air Source Heat Pump*
= *Actual*

For example, a 3 ton unit with a SEER rating of 14.5 and HSPF of 8.4 in Baltimore, MD:

$$\Delta kWH = (531 * 36{,}000 * (1/13 - 1/14.5))/1{,}000 + (1{,}195 * 36{,}000 * (1/7.7 - 1/8.4))/1{,}000$$

$$= 618\ kWh$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = BtuH * (1/EERbase - 1/EERee))/1{,}000 * CF$$

Where:

EERbase = *Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump*
= *11* [135]

EERee = *Energy Efficiency Ratio (EER) of Efficient Air Source Heat Pump*
= *Actual*
If EER is unknown, calculate based on SEER[136]*:*
$= (-0.02 * SEER^2) + (1.12 * SEER)$

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [137]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [138]

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[135] Minimum Federal Standard

[136] Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Master's Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

[137] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

[138] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the PJM Peak Definition coincidence factor is 0.66.

For example, a 3 ton unit with EER rating of 12.0 in Baltimore, MD:

$$\Delta kW = 36{,}000 * (1/11 - 1/12))/1{,}000 * 0.69$$

$$= 0.19\ kW$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided in the table below[139]. Note these incremental costs are per ton of capacity, so for example a 3 ton, 15 SEER unit would have an incremental cost of $822.

Efficiency (SEER)	Incremental Cost per Ton of Capacity
14	$137
15	$274
16	$411
17	$548
18	$685

Measure Life

The measure life is assumed to be 18 years[140].

Operation and Maintenance Impacts

n/a

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[139] DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

[140] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

HE Gas Boiler

Unique Measure Code: RS_HV_TOS_GASBLR_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure characterization provides savings for the purchase and installation of a new residential sized ENERGY STAR-qualified high efficiency gas-fired boiler for residential space heating, instead of a new baseline gas boiler. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Definition of Baseline Condition

The baseline condition is a boiler that meets the minimum Federal baseline AFUE for boilers of 80 %.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified boiler with an AFUE rating ≥ 85%.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = (FLHheat * (Btuh/AFUEbase - Btuh/AFUEee)) /1,000,000$$

Where:

FLHheat = Full Load Heating Hours
= 620[141]

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[141] Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program,

BtuH = *Capacity of Boiler*
= *Actual*
AFUEbase = *Efficiency in AFUE of baseline boiler*
= *0.80* [142]
AFUEee = *Efficiency in AFUE of efficient boiler*
= *Actual*

For example, the purchase and installation of a 100,000 Btuh, 90% AFUE boiler:

$$\Delta \text{MMBtu} = (620 * (100{,}000/0.8 - 100{,}000/0.9)) / 1{,}000{,}000$$

$$= 8.6 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided below[143]:

Efficiency of Boiler (AFUE)	Incremental Cost
85% - 90%	$934
91% +	$1481

Measure Life

The measure life is assumed to be 18 years[144] .

Operation and Maintenance Impacts

n/a

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technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHheat assumption.

[142] Federal baseline AFUE for boilers.

[143] Costs derived from Page E-13 of Appendix E of Residential Furnaces and Boilers Final Rule Technical Support Document:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html
VEIC believes it is reasonable to assume that the cost provided from this study for an 85% unit is appropriate for units in the 85-90% AFUE range and the cost for the 91% unit can be used for 91+% units. This is based on the observation that most of the products available in the 85-90 range are in the lower end of the range, as are those units available above 91% AFUE.

[144] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Condensing Furnace (gas)

Unique Measure Code: RS_HV_TOS_GASFUR_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure characterization provides savings for the purchase and installation of a new residential sized ENERGY STAR-qualified high efficiency gas-fired condensing furnace for residential space heating, instead of a new baseline gas furnace. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Definition of Baseline Condition

The baseline condition is a non-condensing gas furnace with an AFUE of 80 %[145].

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified gas-fired condensing furnace with an AFUE rating ≥ 90%.

Annual Energy Savings Algorithm

n/a. Note, if the furnace has an ECM fan, electric savings should be claimed as characterized in the "Central Furnace Efficient Fan Motor" section of the TRM.

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = (FLHheat * (Btuh/AFUEbase - Btuh/AFUEee)) /1{,}000{,}000$$

Where:

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[145] The Federal baseline for furnaces is actually 78%, however experience suggests a more suitable market baseline is 80% AFUE.

FLHheat = *Full Load Heating Hours*
= *620*[146]
BtuH = *Capacity of Furnace*
= *Actual*
AFUEbase = *Efficiency in AFUE of baseline Furnace*
= *0.80*
AFUEee = *Efficiency in AFUE of efficient Furnace*
= *Actual*

For example, the purchase and installation of a 100,000 Btuh, 92% AFUE furnace:

$$\Delta\text{MMBtu} = (620 * (100{,}000/0.8 - 100{,}000/0.92))\ /1{,}000{,}000$$

$$= 10.1\ \text{MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided below[147]:

Efficiency of Furnace (AFUE)	Incremental Cost
90%	$630
92%	$802
96%	$1,747

Measure Life

The measure life is assumed to be 18 years[148].

Operation and Maintenance Impacts

n/a

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[146] Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHheat assumption.

[147] Costs derived from Page E-3 of Appendix E of Residential Furnaces and Boilers Final Rule Technical Support Document:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html

[148] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Programmable Thermostat

Unique Measure Code: RS_HV_RTR_PRGTHE_V2.0711
Effective Date: July 2011
End Date:

Measure Description

Programmable Thermostats can save energy through the advanced scheduling of setbacks to heating setpoints. Typical usage reduces the heating setpoint during times of the day when occupants are usually not at home (e.g. work hours) or during the night.

Note, savings are only provided for the reduction in heating load for fossil fuel fired heating systems. A literature review could not find any appropriate defensible source of cooling savings from programmable thermostats. It is inappropriate to assume a similar pattern of savings from setting your thermostat down during the heating season and up during the cooling season.

This is a retrofit measure.

Definition of Baseline Condition

A standard, non-programmable thermostat for central heating system (baseboard electric is excluded from this characterization).

Definition of Efficient Condition

A programmable thermostat is installed and programmed by a professional.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = (\text{Savings \%}) \times (\text{Heat Load})$$

Where:

Savings % = *Estimated percent reduction in heating load due to programmable thermostat*
= *6.8%* [149]

Heat Load = *Annual Home Heating load (MMBtu)*
= *50.1* [150]

$$\Delta \text{MMBtu} = 0.068 * 50.1$$

$$= 3.41 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual unit cost and if installed via program administrators should also include labor cost[151].

Measure Life

The measure life is assumed to be 10 years[152].

Operation and Maintenance Impacts

n/a

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[149] 2007, RLW Analytics, "Validating the Impact of Programmable Thermostats"

[150] 50.1 MMBtu heating load is estimated based on the MD Residential Baseline Database, subtracting Base load from Base + Heat.

[151] The range of costs observed in VEIC's review of other utilities TRMs was $35-$40 for the unit, $100 for labor. In the absence of actual program costs, this cost could be used.

[152] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Room Air Conditioner Early Replacement

Unique Measure Code: RS_HV_RTR_RA/CES_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes the early removal of an existing inefficient Room Air Conditioner unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR qualifying unit. This measure is suitable for a Low Income or a Home Performance program.

Savings are calculated between the existing unit and the new efficient unit consumption during the assumed remaining life of the existing unit, and between a hypothetical new baseline unit and the efficient unit consumption for the remainder of the measure life.

This is a retrofit measure.

Definition of Baseline Condition

The baseline condition is the existing inefficient room air conditioning unit for the remaining assumed useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard (i.e. with an efficiency rating of 9.8EER).

Definition of Efficient Condition

The efficient condition is a new replacement room air conditioning unit meeting the ENERGY STAR efficiency standard (i.e. with an efficiency rating greater than or equal to 10.8EER).

Annual Energy Savings Algorithm

Savings for remaining life of existing unit (1st 3 years)

$$\Delta kWh = (Hours * BtuH * (1/EERexist - 1/EERee))/1{,}000$$

Savings for remaining measure life (next 9 years)

$$\Delta kWh = (Hours * BtuH * (1/EERbase - 1/EERee))/1{,}000$$

Where:

Hours = *Run hours of Window AC unit*
= *325* [153]
Btuh = *Capacity of replaced unit*
= *Actual or 8,500 if unknown* [154]
EERexist = *Efficiency of existing unit in Btus per Watt-hour*
= *7.7* [155]
EERbase = *Efficiency of baseline unit in Btus per Watt-hour*
= *9.8* [156]
EERee = *Efficiency of ENERGY STAR unit in Btus per Watt-hour*
= *Actual*

For example, an 8,500 Btuh Room AC unit with an EER rating of 10.8:

Savings for remaining life of existing unit (1st 3 years)

$$\Delta kWh = (325 * 8,500 * (1/7.7 - 1/10.8)) / 1,000$$

$$= 103 \text{ kWh}$$

Savings for remaining measure life (next 9 years)

$$\Delta kWh = (325 * 8,500 * (1/9.8 - 1/10.8)) / 1,000$$

$$= 26 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

Savings for remaining life of existing unit (1st 3 years)

$$\Delta kW = ((BtuH * (1/EERexist - 1/EERee))/1000) * CF$$

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[153] VEIC calculated the average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) at 31%. Applying this to the FLH for Central Cooling provided for Baltimore (1050) we get 325 FLH for Room AC.

[154] Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[155] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

[156] Minimum Federal Standard for capacity range.

Savings for remaining measure life (next 9 years)

$\Delta kW = ((BtuH * (1/EERbase - 1/EERee))/1000) * CF$

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [157]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.3*[158]

For example, a 8500 Btuh Room AC unit with an EER rating of 10.8

Savings for remaining life of existing unit (1st 3 years)

$\Delta kW_{SSP} = ((8{,}500 * (1/7.7 - 1/10.8)) / 1{,}000) * 0.31$

$= 0.098$ kW

Savings for remaining measure life (next 9 years)

$\Delta kW_{SSP} = ((8{,}500 * (1/9.8 - 1/10.8)) / 1{,}000) * 0.31$

$= 0.025$ kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual cost of the replacement unit and any cost of installation labor.

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[157] Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

[158] Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008
(http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf).

Note, the deferred baseline replacement cost is presented under Operation and Maintenance Impacts.

Measure Life

The measure life is assumed to be 12 years[159]. Note this characterization also assumes there is 3 years of remaining useful life of the unit being replaced[160].

Operation and Maintenance Impacts

The net present value of the deferred replacement cost (the cost associated with the replacement of the existing unit with a standard unit that would have occurred in 3 years, had the existing unit not been replaced) should be calculated as:

$NPV_{\text{deferred replacement cost}}$ = (Actual Cost of ENERGY STAR unit - $40[161]) * 69%[162].

Note that this is a lifecycle cost savings (i.e. a negative cost).

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[159] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

[160] Based on Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year

[161] Incremental cost of ENERGY STAR unit over baseline unit; consistent with Time of Sale Room AC measure.

[162] 69% is the ratio of the Net Present Value (with a 5% discount rate) of the annuity payments from years 4 to 12 of a deferred replacement of a standard efficiency unit. The calculation is done in this way to allow the use of the known ENERGY STAR replacement cost to calculate an appropriate baseline replacement cost.

Room Air Conditioner Early Retirement / Recycling

Unique Measure Code: RS_HV_ERT_RA/C_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes the savings resulting from implementing a drop off service taking existing working inefficient Room Air Conditioner units from service, prior to their natural end of life. This measure assumes that a percentage of these units will ultimately be replaced with a baseline standard efficiency unit (note that if it is actually replaced by a new ENERGY STAR qualifying unit, the savings increment between baseline and ENERGY STAR should be captured under the ENERGY STAR Room AC Time of Sale measure).

Definition of Baseline Condition

The baseline condition is the existing inefficient room air conditioning unit.

Definition of Efficient Condition

Not applicable. This measure relates to the retiring of an existing inefficient unit. A percentage of units however are assumed to be replaced with a baseline new unit and the savings are therefore reduced to account for these replacement units.

Annual Energy Savings Algorithm

$$\Delta kWh = ((Hours * BtuH * (1/EERexist))/1{,}000) - (\%replaced * ((Hours * BtuH * (1/EERnewbase))/1{,}000)$$

Where:

Hours = Run hours of Window AC unit
= 325 [163]

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[163] VEIC calculated the average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) at

Btu/hour = *Capacity of replaced unit*
= *Actual or 8,500 if unknown* [164]

EERexist = *Efficiency of existing unit in Btus per Watt-hour*
= *Actual or 7.7 if unknown* [165]

%replaced = Percentage of units dropped off that are replaced in the home
= 76% [166]

EERnewbase = *Efficiency of new baseline unit in Btus per Watt-hour*
= 9.8[167]

For example, the turn in of an 8,500 Btuh, 7.7 EER unit:

$$\Delta kWh = ((325 * 8{,}500 * (1/7.7))/1{,}000) - (0.76 * ((325 * 8{,}500 * (1/9.8))/1{,}000)$$

$$= 145 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((BtuH * (1/EERexist))/1{,}000) - (\%replaced * ((BtuH * (1/EERnewbase))/1{,}000) * CF$$

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [168]

31%. Applying this to the FLH for Central Cooling provided for Baltimore (1050) we get 325 FLH for Room AC.

[164] Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[165] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

[166] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report." Report states that 63% were replaced with ENERGY STAR units and 13% with non-ENERGY STAR. However this formula assumes all are non-ENERGY STAR since the increment of savings between baseline units and ENERGY STAR would be recorded by the Time of Sale measure when the new unit is purchased.

[167] Minimum Federal Standard for capacity range. Note that we assume the replacement is only at federal standard efficiency for the reason explained above.

[168] Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.3*[169]

For example, the turn in of an 8500 Btuh, 7.7 EER unit:

$$\Delta kW_{SSM} = ((8{,}500 * (1/7.7))/1{,}000) - (0.76 * ((8{,}500 * (1/9.8))/1{,}000) * 0.31$$

$$= 0.9 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual implementation cost for recycling the existing unit, plus $129 to account for the replacement of 76% of the units[170].

Measure Life

The measure life is assumed to be 3 years[171].

Operation and Maintenance Impacts

The net present value of the deferred replacement cost (the cost associated with the replacement of those units that would be replaced, with a standard unit that would have had to have occurred in 3 years, had the existing unit not been replaced) is calculated as $89.36[172].

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[169] Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf).

[170] $129 replacement cost is calculated by multiplying the percentage assumed to be replaced - 76% by the assumed cost of a standard efficiency unit of $170 (ENERGY STAR calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls); 0.76 * 170 = $129.2.

[171] 3 years of remaining useful life based on Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year

[172] Determined by calculating the Net Present Value (with a 5% discount rate) of the annuity payments from years 4 to 12 of a deferred replacement of a standard efficiency unit costing

Domestic Hot Water (DHW) End Use

Low Flow Shower Head

Unique Measure Code(s): RS_WT_INS_SHWRHD_V1.0510 and RS_WT_TOS_SHWRHD_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the installation of a low flow (2.0 GPM) showerhead in a home. This is a retrofit direct install measure or a new installation.

Definition of Baseline Condition

The baseline is a standard showerhead using 2.5 GPM.

Definition of Efficient Condition

The efficient condition is an energy efficient showerhead using 2.0 GPM.

Annual Energy Savings Algorithm

If electric domestic water heater:

ΔkWH[173] = ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year) / SH/home * 8.3 * (TEMPsh - TEMPin) / 1,000,000) / DHW Recovery Efficiency / 0.003412

Where:

GPMbase = Gallons Per Minute of baseline showerhead

---

multiplied by the 76%, the percentage of units being replaced (i.e. 0.76 * $170 = $129.2. Baseline cost from ENERGY STAR calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls)

[173] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all showerhead installations.

= 2.5 [174]

GPMlow = Gallons Per Minute of low flow showerhead
= 2.0 [175]

\# people = Average number of people per household
= 2.56 [176]

gals/day = Average gallons per day used for showering
= 11.6 [177]

days/y = Days shower used per year
= 365

Showers/home = Average number of showers in the home
= 1.6 [178]

8.3 = Constant to convert gallons to lbs

TEMPsh = Assumed temperature of water used for shower
= 105 [175]

TEMPin = Assumed temperature of water entering house
= 55 [179]

DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.98 [180]

0.003412 = Constant to convert MMBtu to kWh

$$\Delta kWH = ((((2.5 - 2.0) / 2.5) * 2.56 * 11.6 * 365) / 1.6 * 8.3 * (105-55) / 1{,}000{,}000) / 0.98 / 0.003412$$

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[174] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

[175] Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year.

[176] US Energy Information Administration, Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf

[177] Most commonly quoted value of gallons of water used per person per day (including in U.S. Environmental Protection Agency's "water sense" documents; http://www.epa.gov/watersense/docs/home_suppstat508.pdf)

[178] Estimate based on review of a number of studies:
a. Pacific Northwest Laboratory; "Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications" http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?purl=/10185385-CEkZMk/native/
b. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

[179] A good approximation of annual average water main temperature is the average annual ambient air temperature. 55 degrees used based on: http://lwf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal_hires.jpg

[180] Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

= 168 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh/hours * CF

Where:

Hours = *Average number of hours per year spent using shower head*
= *(Gal/person * # people * 365) / SH/home / GPM / 60*
= *(11.6 * 2.56 * 365) / 1.6 / 2.5 / 60*
= *45 hours*

CF = *Summer Peak Coincidence Factor for measure*
= *0.00371* [181]

ΔkW = 168 / 45 * 0.00371

= 0.0138 kW

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater:

ΔMMBtu = ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year)) / SH/home * 8.3 * (TEMPsh - TEMPin) / 1,000,000) / Gas DHW Recovery Efficiency

Where:

Gas DHW Recovery Efficiency = *Recovery efficiency of electric water heater*
= *0.75* [182]

All other variables *As above*

ΔMMBtu = ((((2.5 - 2.0) / 2.5) * 2.56 * 11.6 * 365) / 1.6 * 8.3 * (105-55) / 1,000,000) / 0.75

---

[181] Calculated as follows: Assume 9% showers take place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
9% * 7.42 minutes per day (11.6 * 2.56 / 1.6 / 2.5 = 7.42) = 0.668 minutes
= 0.668 / 180 (minutes in peak period) = 0.00371

[182] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

= 0.7497 MMBtu

Annual Water Savings Algorithm

Water Savings = (((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year) / SH/home /748

Where:

748 = *Constant to convert from gallons to CCF*

All other variables *As above*

Water Savings = ((((2.5 - 2.0) / 2.5) * 2.56 * 11.6 * 365)) / 1.6 / 748

= 1.81 CCF

Incremental Cost

As a retrofit measure, the incremental cost will be the actual cost of installing the new showerhead. As a time of sale measure, the incremental cost is assumed to be $6.[183]

Measure Life

The measure life is assumed to be 10 years.[184]

Operation and Maintenance Impacts

When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

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[183] Navigant Consulting, Ontario Energy Board, "Measures and Assumptions for Demand Side Management (DSM) Planning", April 2009.

[184] Consistent with assumptions provided on page C-6 of Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. (http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf)

Faucet Aerators

Unique Measure Code(s): RS_WT_INS_FAUCET_V1.0510 and RS_WT_TOS_FAUCET_V1.0510
Effective Date: May 2010
End Date:

Measure Description

This measure relates to the installation of a low flow (1.5 GPM) faucet aerator in a home. This could be a retrofit direct install measure or a new installation.

Definition of Baseline Condition

The baseline is a standard faucet aerator using 2.2 GPM.

Definition of Efficient Condition

The efficient condition is an energy efficient faucet aerator using 1.5 GPM.

Annual Energy Savings Algorithm

If electric domestic water heater:

$$\Delta \text{kWH}[185] = (((((\text{GPMbase} - \text{GPMlow}) / \text{GPMbase}) * \# \text{ people} * \text{gals/day} * \text{days/year} * \text{DR}) / (\text{F/home})) * 8.3 * (\text{TEMPft} - \text{TEMPin}) / 1{,}000{,}000) / \text{DHW Recovery Efficiency} / 0.003412$$

Where:

GPMbase = Gallons Per Minute of baseline faucet
= 2.2 [186]

GPMlow = Gallons Per Minute of low flow faucet
= 1.5 [187]

---

[185] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.

[186] In 1998, the Department of Energy adopted a maximum flow rate standard of 2.2 gpm at 60 psi for all faucets: 63 Federal Register 13307; March 18, 1998.

[187] Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year.

 # people = *Average number of people per household*
= *2.56*[188]

gals/day = *Average gallons per day used by faucet*
= *10.9*[189]

days/y = *Days faucet used per year*
= *365*

DR = *Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)*
= *50%*[190]

F/home = *Average number of faucets in the home*
= *3.5*[191]

8.3 = *Constant to convert gallons to lbs*

TEMPft = *Assumed temperature of water used by faucet*
= *80*[187]

TEMPin = *Assumed temperature of water entering house*
= *55*[192]

DHW Recovery Efficiency = *Recovery efficiency of electric water heater*
= *0.98*[193]

0.003412 = *Constant to converts MMBtu to kWh*

$$\Delta kWH = ((((2.2 - 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 * 8.3 * (80-55) / 1{,}000{,}000) / 0.98 / 0.003412$$

$$= 29 \text{ kWh}$$

---

[188] US Energy Information Administration, Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf

[189] Most commonly quoted value of gallons of water used per person per day (including in U.S. Environmental Protection Agency's "water sense" documents; http://www.epa.gov/watersense/docs/home_suppstat508.pdf)

[190] Estimate consistent with Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."

[191] Estimate based on East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

[192] A good approximation of annual average water main temperature is the average annual ambient air temperature. 55 degrees used based on: http://lwf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal_hires.jpg

[193] Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh/hours * CF

Where:

Hours = *Average number of hours per year spent using faucet*
= *(Gal/person * # people * 365) /(F/home) / GPM / 60*
= *(10.9 * 2.56 * 365) / 3.5 / 2.2 / 60*
= *22 hours*

CF = *Summer Peak Coincidence Factor for measure*
= *0. 00262* [194]

ΔkW = 29 / 22 * 0.00262

= 0.0034 kW

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater, MMBtu savings provided below:

ΔMMBtu = ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / (F/home) * 8.3 * (TEMPft - TEMPin) / 1,000,000) / Gas DHW Recovery Efficiency

Where:

Gas DHW Recovery Efficiency = *Recovery efficiency of electric water heater*
= *0.75* [195]

All other variables *As above*

ΔMMBtu = ((((2.2 - 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 * 8.3 * (80-55) / 1,000,000) / 0.75

= 0.128 MMBtu

---

[194] Calculated as follows: Assume 13% faucet use takes place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf) 13% * 3.6 minutes per day (10.9 * 2.56 / 3.5 / 2.2 = 3.6) = 0.47 minutes = 0.47 / 180 (minutes in peak period) = 0.00262

[195] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

Annual Water Savings Algorithm

Water Savings = (((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / (F/home) /748

Where:

748 = *Constant to convert from gallons to CCF*

All other variables *As above*

Water Savings = (((2.2 - 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 / 748

= 0.619 CCF

Incremental Cost

As a retrofit measure, the incremental cost will be the actual cost of installing the new aerator. As a time of sale measure, the incremental cost is assumed to be $2.[196]

Measure Life

The measure life is assumed to be 5 years.[197]

Operation and Maintenance Impacts

When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

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[196] Navigant Consulting, Ontario Energy Board, "Measures and Assumptions for Demand Side Management (DSM) Planning", April 2009.

[197] Conservative estimate based on review of TRM assumptions from other States.

Domestic Hot Water Tank Wrap

Unique Measure Code(s): RS_WT_INS_HWWRAP_V1.0510
Effective Date: May 2010
End Date:

Measure Description

This measure relates to a Tank Wrap or insulation "blanket" that is wrapped around the outside of a hot water tank to reduce stand-by losses. This measure applies only for homes that have an electric water heater that is not already well insulated.

Definition of Baseline Condition

The baseline condition is a standard electric domestic hot water tank without an additional tank wrap.

Definition of Efficient Condition

The efficient condition is the same standard electric domestic hot water tank with an additional tank wrap.

Annual Energy Savings Algorithm

$$\Delta \text{kWH} = \text{KWHbase} * ((\text{EFnew} - \text{EFbase})/\text{EFnew})$$

Where:

KWHbase = Average KWH consumption of electric domestic hot water tank = 3460 [198]

EFnew installed = Assumed efficiency of electric tank with tank wrap = 0.88 [199]

---

[198] Assumption taken from; Residential Water Heaters Technical Support Document for the January 17, 2001, Final Rule
Table 9.3.9, p9-34,
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/09.pdf
Consistent with FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters
http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf

[199] The Oak Ridge study predicted that wrapping a 40 gal water heater would increase Energy Factor of a 0.86 electric DHW tank by 0.02 (to 0.88);

EFbase installed = *Assumed efficiency of electric tank without tank wrap*

= 0.86 [199]

$$\Delta kWH = 3460 * ((0.88-0.86)/0.88)$$

$$= 79 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh/8760$$

Where:

ΔkWh = *kWh savings from tank wrap installation*

8760 = *Number of hours in a year (since savings are assumed to be constant over year).*

$$\Delta kW = 79 \ / \ 8760$$

$$= 0.0090 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure will be the actual cost of installing the tank wrap.

Measure Life

The measure life is assumed to be 5 years.[200]

Operation and Maintenance Impacts

n/a

"Meeting the Challenge: The Prospect of Achieving 30 percent Energy Savings Through the Weatherization Assistance Program" by the Oak Ridge National Laboratory - May 2002. http://www.cee1.org/eval/db_pdf/309.pdf

[200] Conservative estimate that assumes the tank wrap is installed on an existing unit with 5 years remaining life.

DHW pipe insulation

Unique Measure Code: RS_WT_RTR_PIPEIN_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to the first elbow of the hot water carrying pipe.

Note, the algorithm provided to calculate savings may be used to determine an appropriate deemed savings value if the programs can provide appropriate average values for each of the variables.

This is a retrofit measure.

Definition of Baseline Condition

The baseline condition is un-insulated hot water carrying copper pipes.

Definition of Efficient Condition

To efficiency case is installing pipe wrap insulation to the first elbow of the hot water carrying copper pipe.

Annual Energy Savings Algorithm

If electric domestic hot water tank:

$$\Delta kWh = ((1/Rexist - 1/Rnew) * (L * C) * \Delta T * 8{,}760) / \eta DHW / 3413$$

Where:

Rexist = *Assumed R-value of existing uninsulated piping*
= *1.0*[201]

Rnew = *R-value of existing pipe plus installed insulation*
= *Actual*

---

[201] Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77, presented to the Ontario Energy Board: http://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

Length = *Length of piping insulated*
= *Actual*
Circumference = *Circumference of piping*
= *Actual (0.5" pipe = 0.13ft, 0.75" pipe = 0.196ft)*
ΔT = *Temperature difference between water in pipe and ambient air*
= *65°F*[202]
8,760 = *Hours per year*
ηDHW = *DHW Recovery efficiency* (ηDHW)
= *0.98*[203]
3413 = *Conversion from Btu to kWh*

For example, insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\Delta kWh = ((1/1.0 - 1/4.5) * (4 * 0.196) * 65 * 8{,}760) / 0.98 / 3{,}413$$

$$= 104 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / 8{,}760$$

For example, insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\Delta kW = 104 / 8{,}760$$

$$= 0.012 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

If fossil fuel DHW unit:

$$\Delta MMBtu = ((1/Rexist - 1/Rnew) * (L * C) * \Delta T * 8{,}760) / \eta DHW / 1{,}000{,}000$$

Where:
ηDHW = *Recovery efficiency of gas hot water heater*

---

[202] Assumes 130°F water leaving the hot water tank and average temperature of basement of 65°F.
[203] Electric water heaters have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

= *0.75* [204]

For example, insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\Delta MMBtu = ((1/1.0 - 1/4.5) * (4 * 0.196) * 65 * 8,760)/ 0.75 / 1,000,000$$

$$= 0.46 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual cost of material and labor. If this is not available, assume $3 per foot of insulation[205].

Measure Life

The measure life is assumed to be 15 years[206].

Operation and Maintenance Impacts

n/a

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[204] Review of AHRI Directory suggests range of recovery efficiency ratings for *new* Gas DHW units of 70-87%. Average of *existing* units is estimated at 75%

[205] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

[206] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

High Efficiency Gas Water Heater

Unique Measure Code: RS_WT_TOS_GASDHW_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes the purchase of a high efficiency gas water heater meeting or exceeding ENERGY STAR criteria for the water heater category provided below, in place of a new unit rated at the minimum Federal Standard. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Definition of Baseline Condition

The baseline condition is a new 50 gallon conventional gas storage water heater rated at the federal minimum 0.58 EF[207].

Definition of Efficient Condition

The efficient condition is a new high efficiency gas water heater meeting or exceeding the minimum efficiency Energy Star qualification criteria provided below[208]:

Water Heater Type	Energy Factor
High Efficiency Gas Storage	0.67
Gas Condensing	0.80
Whole Home Gas Tankless	0.82

---

[207] The Baseline Energy Factor is based on the Federal Minimum Standard for a standard 50 gallon storage water heater. Currently this is calculated as 0.67 - (0.0019 * Rated Volume) = 0.575 EF. This ruling can be found here:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf
Please note that there is a new standard that will come in to force for water heaters sold on or after April 16 2015. This will increase the Federal standard to 0.675 - (0.0015 * Rated Volume) = 0.6 EF:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_fedreg.pdf

[208] http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = MMBtuDHW * ((EFEff - EFBase) / EFEff)$$

Where:

MMBtuDHW = *typical annual household hot water consumption (based on existing units)*
= *21.1*[209]

EF_{Base} = *Baseline Energy Factor*
= *0.575*[210]

EF_{Eff} = *Efficient Energy Factor*
= *Actual*[211]

For example, purchase and installation of a 0.82 gas condensing water heater:

$$\Delta MMBtu = 21.1 * ((0.82 - 0.575) / 0.82)$$

$$= 6.3 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

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[209] The estimate for hot water consumption for *existing* units is 23.1MMBtu, based on US EIA, Residential Energy Consumption Survey; Average Consumption for Water Heating by Major Fuels Used, 2005 http://www.eia.doe.gov/emeu/recs/recs2005/c&e/waterheating/pdf/tablewh7.pdf VEIC estimate that the average efficiency of the existing DHW unit stock is 52.5% (based on the Federal Minimum standard from 1991 to 2001 (0.62 - (0.0019*50) = 0.525). An estimate of a new baseline unit energy consumption is therefore calculated as 23.1 * (0.525/0.575) = 21.1MMBtu.

[210] Minimum Federal Standard for a 50gallon gas fired tank; 0.67 - (0.0019 × Rated Storage Volume in gallons); http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf

[211] The minimum ENERGY STAR specifications are provided above.

Incremental Cost

The incremental cost for this measure is provided below[212]:

Water Heater Type	Incremental Cost
High Efficiency Gas Storage	$175
Gas Condensing	$1,150
Whole Home Gas Tankless	$750

Measure Life

The measure life is assumed to be 13 years[213].

Operation and Maintenance Impacts

n/a

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[212] Incremental costs based on ACEEE lifecycle cost analysis; http://www.aceee.org/node/3068#lcc. High efficiency gas storage units cost $1025, condensing gas units cost $2000 and tankless units cost $1600, compared to a conventional unit cost of $850.

[213] Based on ACEEE Life-Cycle Cost analysis; http://www.aceee.org/node/3068#lcc

Heat Pump Domestic Water Heater

Unique Measure Code(s): RS_WT_TOS_HPRSHW_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the installation of a Heat Pump domestic water heater in place of a standard electric water heater in conditioned space. This is a time of sale measure.

Definition of Baseline Condition

The baseline condition is a standard electric water heater.

Definition of Efficient Condition

The efficient condition is a heat pump water heater.

Annual Energy Savings Algorithm

$$\Delta kWH = KWHbase * ((EFnew - EFbase)/EFnew) + KWHcooling - KWHheating$$

Where:

KWHbase = *Average electric DHW consumption*
= *3460* [214]

EFnew = *Energy Factor of Heat Pump water heater*
= *2.0* [215]

EFbase = *Energy Factor of standard electric water heater*
= *0.904* [216]

---

[214] Assumption taken from; Residential Water Heaters Technical Support Document for the January 17, 2001, Final Rule
Table 9.3.9, p9-34,
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/09.pdf
Consistent with FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters
http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf

[215] Efficiency based on ENERGY STAR Residential Water Heaters, Final Criteria Analysis: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterDraftCriteriaAnalysis.pdf

KWHcooling = Cooling savings from conversion of heat in home to water heat

= 61[217]

KWHheating[218] *= Heating cost from conversion of heat in home to water heat*

KWHheating (electric resistance) = 1043
KWHheating (heat pump COP 2.0) = 521
KWHheating (fossil fuel) = 0

ΔkWH electric resistance heat = 3460 * ((2.0 - 0.904) / 2.0) + 61 - 1043
= 914 kWh

ΔkWH heat pump heat = 3460 * ((2.0 – 0.904) / 2.0) + 61 - 521
= 1436 kWh

ΔkWH fossil fuel heat = 3460 * ((2.0 - 0.904) / 2.0) + 61 - 0
= 1957 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0.17 kW [219]

Annual Fossil Fuel Savings Algorithm

ΔMMBtu = -KWHheating (electric resistance) * 0.003412 / AFUEheating[220]
= -1043 *.003412 / .80
= -4.45 MMBTU[221]

---

[216] As above

[217] Cooling kWh= KWHbase * ((EFnew - EFbase)/EFnew)/8760 * 829 cooling hours (from TMY Baltimore data) / SEER 10 / 3.412 BTU/Wh

[218] Heating kWh= KWHbase * ((EFnew - EFbase)/EFnew)/8760 * 4818 cooling hours (from TMY Baltimore data) / heating system efficiency

[219] Based on a chart showing summer weekday average electrical demand on page 10 of FEMP Study "Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters" (http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf). Using data points from the chart, the average delta kW in heat pump mode during the peak hours compared to resistance mode is 0.17kW.

[220] This is the additional energy consumption required to replace the heat removed from the home during the heating season by the heat pump water heater. KWHheating (electric resistance) is that additional heating energy for a home with electric resistance heat. This formula converts the additional heating kWh for an electric resistance home to the MMBtu required in a fossil fuel heated home.

[221] Negative value because heating energy will increase due to this measure.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $925.[222]

Measure Life

The measure life is assumed to be 10 years.[223]

Operation and Maintenance Impacts

n/a

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[222] Vermont Energy Investment Corporation "Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status" November 2005.

[223] Based on ENERGY STAR Residential Water Heaters, Final Criteria Analysis: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterDraftCriteriaAnalysis.pdf

Laundry End Use

Clothes Washer

Unique Measure Code(s): RS_LA_TOS_CWASHES_V1.0510 and RS_LA_TOS_CWASHT3_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the purchase (time of sale) and installation of a clothes washer exceeding either the ENERGY STAR (note the ENERGY STAR specification was changed as of January 1st 2011) or CEE TIER 3 minimum qualifying efficiency standards presented below:

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
Federal Standard 2010	>= 1.26	No requirement
Federal Standard 2011	>= 1.26	<= 9.5
ENERGY STAR 2010	>= 1.80	<= 7.5
ENERGY STAR 2011	>= 2.20	<= 6.0
CEE TIER 3	>= 2.20	<= 4.5

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
Federal Standard	>= 1.26	No requirement
ENERGY STAR	>= 1.80	<= 7.5
CEE TIER 3	>= 2.20	<= 4.5

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry can be washed and dried with one kWh of electricity; the higher the number, the greater the efficiency.

The Water Factor is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

Definition of Baseline Condition

The baseline condition is a clothes washer at the minimum federal baseline efficiency presented above. The Federal Standard specification was changed as of January 1st 2011. Savings assumptions for both specifications are provided.

Definition of Efficient Condition

The efficient condition is a clothes washer meeting either the ENERGY STAR or CEE TIER 3 efficiency criteria presented above. The ENERGY STAR specification was changed as of January 1st 2011. Savings assumptions for both specifications are provided.

Annual Energy Savings Algorithm

Savings are determined using Modified Energy Factor assumptions, applying the proportion of consumption used for water heating, clothes washer and clothes dryer operation and then to the mix of domestic hot water heating fuels and dryer fuels. Savings from reduced water usage are also factored in.

For the full calculation see Clothes Washer Work Sheet, but the key assumptions and their sources are provided below:

Washer Volume = 3.23 cubic feet [224]
Baseline MEF = 1.26
ENERGY STAR 2010 MEF = 1.80
ENERGY STAR 2011 MEF = 2.0
CEE TIER 3 MEF = 2.2
Number of cycles per year = 282 [225]
% consumption for water heating, CW operation, Dryer operation = 26%, 7%, 67% [226]

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[224] Average unit size of products participating in the Efficiency Vermont Clothes Washer rebate program.

[225] Weighted average of 2005 Residential Energy Consumption Survey (RECS) for Mid-Atlantic: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc11.10.pdf)

[226] The Clothes Washer Technical Support Document, located at: http://www.eere.energy.gov/buildings/appliance_standards/residential/clwash_0900_r.html Energy and water savings estimates are located in Chapter 4, Engineering Analysis, Table 4.1, Page 4-5

Water savings per load (ENERGY STAR 2010)
= 28.1 gallons [227]

Water savings per load (ENERGY STAR 2011)
= 11.3 gallons [228]

Water savings per load (CEE TIER 3)
= 16.2 gallons [227]

Community/Municipal Water and Wastewater pump kWh savings per gallon water saved
= 0.0039kWh per gallon of water saved[229]

Mid-Atlantic DHW fuel mix[230]:

Fuel	% of Homes
Electric	18%
Natural Gas	61%
Oil	17%
Propane	3%

Mid-Atlantic Dryer fuel mix:[231]

Fuel	% of Homes
Electric	61%
Natural Gas	39%

$\Delta kWH_{ENERGY\ STAR\ 2010} = 145.1\ kWh$

$\Delta kWH_{ENERGY\ STAR\ 2011} = 153.2\ kWh$

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http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/chapter_4_engineering.pdf

[227] Calculated using baseline Water Factor of 16.2, derived using assumptions from the ENERGY STAR calculator. See Clothes Washer Worksheet for more information. (http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CW)

[228] Note that in 2011 a Federal Standard Water Factor is introduced (<=9.5). This is used in the calculation of savings for ENERGY STAR 2011 units and CEE Tier 3 units.

[229] Efficiency Vermont analysis of Community/Municipal Water and Wastewater pump energy consumption showed 0.0024 kWh pump energy consumption per gallon of water supplied, and 0.0015 kWh consumption per gallon for waste water treatment.

[230] 2005 Residential Energy Consumption Survey (RECS) for Mid-Atlantic: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc8waterheating/pdf/tablehc11.8.pdf)

[231] 2005 Residential Energy Consumption Survey (RECS) for Mid-Atlantic: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc9homeappliance/pdf/tablehc11.9.pdf)

$\Delta kWH_{CEE\ TIER\ 3}$ = 180.4 kWh

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh / Hours * CF$

Where:

Hours = *Assumed Run hours of Clothes Washer*
= *282* [232]

CF = *Summer Peak Coincidence Factor for measure*
= *0.033* [233]

$\Delta kW_{ENERGY\ STAR\ 2010}$ = 145.1 / 282 * 0.033

= 0.017 kW

$\Delta kW_{ENERGY\ STAR\ 2011}$ = 153.2 / 282 * 0.033

= 0.018 kW

$\Delta kW_{CEE\ TIER\ 3}$ = 180.4 / 282 * 0.033

= 0.021 kW

Annual Fossil Fuel Savings Algorithm

For calculation see Clothes Washer Work Sheet. Savings are based on the mix of domestic hot water heating fuels and Dryer fuels.

ENERGY STAR 2010 unit:

MMBtu Savings Natural Gas = 0.342 MMBtu
MMBtu Savings Oil = 0.041 MMBtu
MMBtu Savings Propane = 0.008 MMBtu

ENERGY STAR 2011 unit:

MMBtu Savings Natural Gas = 0.422 MMBtu
MMBtu Savings Oil = 0.051 MMBtu

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[232] Based on assumption of 1 hour average per cycle. # cycles based on weighted average of 2005 Residential Energy Consumption Survey (RECS) for Mid-Atlantic (see CW Work Sheet). http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc11.10.pdf

[233] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

MMBtu Savings Propane = 0.010 MMBtu

CEE TIER 3 unit:

MMBtu Savings Natural Gas = 0.487 MMBtu
MMBtu Savings Oil = 0.059 MMBtu
MMBtu Savings Propane = 0.012 MMBtu

Annual Water Savings Algorithm

For calculation see Clothes Washer Work Sheet.

ENERGY STAR 2010 unit:

Water Savings = 10.6 CCF

ENERGY STAR 2011 unit:

Water Savings = 4.3 CCF

CEE TIER 3 unit:

Water Savings = 6.1 CCF

Incremental Cost

The incremental cost for this measure is assumed to be $250 for an ENERGY STAR unit and $450 for a CEE TIER 3 unit.[234]

Measure Life

The measure life is assumed to be 14 years.[235]

Operation and Maintenance Impacts

n/a

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[234] Survey conducted by Applied Proactive Technologies (APT), Springfield, MA.

[235] Efficiency Vermont TRM.

Shell Savings End Use

Air sealing

Unique Measure Code: RS_SL_RTR_AIRSLG_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure characterization provides a method of claiming both heating and cooling (where appropriate) savings from the improvement of a residential building's air-barrier, which together with its insulation defines the thermal boundary of the conditioned space.

The measure assumes that a trained auditor, contractor or utility staff member is on location, and will measure and record the existing and post air-leakage rate using a blower door in accordance with industry best practices[236]. Where possible, the efficiency of the heating and cooling system used in the home should be recorded, but default estimates are provided if this is not available.

This is a retrofit measure.

Definition of Baseline Condition

The existing air leakage prior to any air sealing work should be determined using a blower door.

Definition of Efficient Condition

Air sealing materials and diagnostic testing should meet all program eligibility qualification criteria. The post air sealing leakage rate should then be determined using a blower door.

Annual Energy Savings Algorithm

Cooling savings from reduction in Air Conditioning Load:

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[236] See BPI Building Analyst and Envelope Professional standards, http://www.bpi.org/standards_approved.aspx

$$\Delta kWh = [(((CFM50Exist - CFM50New) / N\text{-}factor) * 60 * CDH * DUA * 0.018) / 1{,}000 / \eta Cool] * LM$$

Where:

CFM50exist = *Blower Door result (CFM_{50}) prior to air sealing*
= *actual*

CFMnew = *Blower Door result (CFM_{50}) after air sealing*
= *actual*

N-factor = *conversion from CFM_{50} to $CFM_{Natural}$*[237]
= *dependent on exposure level:*

Exposure	*Well Shielded*	*24*
	Normal	*20*
	Exposed	*18*

CDH = *Cooling Degree Hours*[238]
= *dependent on location:*

Location	***Cooling Degree Hours (75° F set point)***
Wilmington, DE	*7,514*
Baltimore, MD	*9,616*
Washington, DC	*13,178*

DUA = *Discretionary Use Adjustment*[239]
= *0.75*

0.018 = *The volumetric heat capacity of air (Btu/ft3°F)*

ηCool = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available use*[240]*:*

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[237] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and exposure of the home to wind, based on methodology developed by Lawrence Berkeley Laboratory (LBL). Since there is minimal stack effect due to low delta T, the height of the building is not included in determining n-factor for cooling savings.
http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122

[238] Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used), each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html)

[239] To account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F. Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

LM = *Latent Multiplier*
= *6.9*[241]

For example, a well shielded home in Wilmington, DE with a 12 SEER Air Conditioning unit, has pre and post blower door test results of 3,400 and 2,250.

ΔkWh = [(((3,400 - 2,250) / 24) *60 * 7,514 * 0.75 * 0.018) / 1,000 / 12] * 6.9

= 168 kWh

<u>Heating savings for homes with electric heat (Heat Pump or resistance):</u>

ΔkWh = ((((CFM50Exist – CFM50New) / N-factor) * 60 * 24 * HDD * 0.018) / 1,000,000 / ηHeat) * 293.1

Where:

N-factor = *conversion from CFM_{50} to $CFM_{Natural}$*[242]
= *Based on building height and exposure level:*

	# Stories:	1	1.5	2	3
Exposure	Well Shielded	24	21.6	19.2	16.8
	Normal	20	18	16	14
	Exposed	18	16.2	14.4	12.6

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[240] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[241] The Latent Multiplier is used to convert the Sensible cooling savings calculated to a value representing Sensible and Latent Cooling loads. The value 6.9 is derived from Harriman et al "Dehumidification and Cooling Loads From Ventilation Air", ASHRAE Journal, which provides a Latent to Sensible load ratio for Baltimore, MD of 4.7:0.8. Thus, the total load (i.e. sensible + latent) to sensible load ratio is 5.5 to 0.8, or 6.9 to 1. While this report also provides a value for Wilmington, DE (7.14), because it is very similar and within the likely range of error for this algorithm, and because there is no equivalent value for Washington DC, for simplicity sake we recommend using a single value to account for the latent cooling loads throughout the region.

[242] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location, height of building (stack effect) and exposure of the home to wind, based on methodology developed by Lawrence Berkeley Laboratory (LBL). http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122

HDD = *Heating Degree Days*
= *dependent on location*[243]

Location	*Heating Degree Days (60°F set point)*
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[244]*:*

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*[245]
Heat Pump	*Before 2006*	6.8	2.00
	After 2006	7.7	2.26
Resistance	*n/a*	*n/a*	1.00

293.1 = Converts MMBtu to kWh

For example, a well shielded home in Wilmington, DE with a heat pump with COP of 2.5, has pre and post blower door test results of 3,400 and 2,250.

ΔkWh = [(((3,400 - 2,250) / 24) *60 * 24 * 3,275 * 0.018) / 1,000,000 / 2.5] * 293.1

477 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh / FLHcool * CF

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[243] The 10 year average annual heating degree day value is calculated for each location, using a balance point for heating equipment use of 60 degrees (based on data obtained from http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm). The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

[244] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate.

[245] To convert HSPF to COP, divide the HSPF rating by 3.413.

Where:

FLHcool = *Full Load Cooling Hours*
= *Dependent on location as below:*

Location	**FLHcool**
Wilmington, DE	*513* [246]
Baltimore, MD	*531* [247]
Washington, DC	*668*

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [248]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [249]

For example, a well shielded home in Wilmington, DE with a 12 SEER Air Conditioning unit, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta kW = 168 / 513 * 0.69$$

$$= 0.23 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

<u>For homes with Fossil Fuel Heating:</u>

$$\Delta MMBTU = (((CFM50Exist - CFM50New) / N\text{-}factor) * 60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat$$

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[246] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

[247] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[248] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

[249] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the PJM Peak Definition coincidence factor is 0.66.

Where:

N-factor = *conversion from CFM_{50} to $CFM_{Natural}$*[250]

= *Based on building height and exposure level:*

	# Stories:	1	1.5	2	3
Exposure	Well Shielded	24	21.6	19.2	16.8
	Normal	20	18	16	14
	Exposed	18	16.2	14.4	12.6

HDD = *Heating Degree Days*

= *dependent on location*[251]

Location	***Heating Degree Days (60° F set point)***
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

ηHeat = *Efficiency of Heating equipment (equipment efficiency * distribution efficiency)*

= *actual*[252]*. If not available use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[253]*.*

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[250] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location, height of building (stack effect) and exposure of the home to wind, based on methodology developed by Lawrence Berkeley Laboratory (LBL). http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122

[251] The 10 year average annual heating degree day value is calculated for a number of locations, using a balance point for heating equipment use of 60 degrees (based on data obtained from http://www.engr.udayton.edu/weather/). The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

[252] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.

[253] The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%. The distribution efficiency default is based on assumption that 50% of duct work is inside the envelope, with some leaks and no insulation. VEIC did not have any more specific data to provide any additional defaults.

For example, a well shielded home in Wilmington, DE with a 70% heating system efficiency, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta \text{MMBtu} = (((3{,}400 - 2{,}250) / 24) * 60 * 24 * 3{,}275 * 0.018) / 1{,}000{,}000 / 0.7$$

$$= 5.8 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual installation and labor cost to perform the air sealing work.

Measure Life

The measure life is assumed to be 15 yrs[254].

Operation and Maintenance Impacts

n/a

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[254] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Attic/ceiling/roof insulation

Unique Measure Code: RS_SL_RTR_ATTICI_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure characterization is for the installation of new insulation in the attic/roof/ceiling of a residential building. The measure assumes that an auditor, contractor or utility staff member is on location, and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and where possible the efficiency of the heating and cooling system used in the home.

This is a retrofit measure.

Definition of Baseline Condition

The existing insulation R-value should include the total attic floor / roof assembly. An R-value of 5 should be assumed for the roof assembly plus the R-value of any existing insulation[255]. Therefore if there is no insulation currently present, the R-value of 5 should be used.

Definition of Efficient Condition

The new insulation should meet any qualification criteria required for participation in the program. The new insulation R-value should include the total attic floor /roof assembly and include the effective R-value of any existing insulation that is left in situ.

Annual Energy Savings Algorithm

Savings from reduction in Air Conditioning Load:

$$\Delta kWh = ((1/Rexist - 1/Rnew) * CDH * DUA * Area) / 1,000 / \eta Cool$$

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[255] The R-5 assumption for roof assembly is based on J.Neymark & Associates and National Renewable Energy Laboratory, June 2009; "BESTEST-EX Interim Test Procedure" p27. The attic floor and roof should be modeled as a system including solar gains and attic ventilation, and R-5 is the standard assumption for the thermal resistance of the whole attic/roof system.

Where:

Rexist = R-value of roof assembly plus any existing insulation
= actual (minimum of R-5)

Rnew = R-value of roof assembly plus new insulation
= actual

CDH = Cooling Degree Hours[256]
= dependent on location:

Location	*Cooling Degree Hours (75° F set point)*
Wilmington, DE	*7,514*
Baltimore, MD	*9,616*
Washington, DC	*13,178*

DUA = Discretionary Use Adjustment[257]
= 0.75

Area = square footage of area covered by new insulation
= actual

ηCool = Efficiency in SEER of Air Conditioning equipment
= actual. If not available use[258]*:*

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

For example, insulating 1200 square feet of attic from R-5 to R-30 in a home with a 12 SEER central Air Conditioning unit in Baltimore, MD.

$$\Delta kWh = ((1/5 - 1/30) * 9{,}616 * 0.75 * 1{,}200) / 1{,}000 / 12$$

$$= 120kWh$$

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[256] Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used), each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/)

[257] To account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F. Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[258] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

Savings for homes with electric heat (Heat Pump of resistance):

$$\Delta kWh = (((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat) * 293.1$$

HDD = *Heating Degree Days*
= *dependent on location*[259]

Location	*Heating Degree Days (60° F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

1,000,000 = Converts Btu to MMBtu
ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[260]*:*

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*
Heat Pump	*Before 2006*	*6.8*	*2.00*
	After 2006	*7.7*	*2.26*
Resistance	*n/a*	*n/a*	*1.00*

293.1 = Converts MMBtu to kWh

For example, insulating 1200 square feet of attic from R-5 to R-30 in a home with a 2.5COP Heat Pump in Baltimore, MD.

$$\Delta kWh = (((1/5 - 1/30) * 3457 * 24 * 1{,}200) / 1{,}000{,}000 / 2.5) * 293.1$$

$$= 1{,}945 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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[259] The 10 year average annual heating degree day value is calculated for a number of locations, using a balance point for heating equipment use of 60 degrees (based on data obtained from http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm). The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

[260] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

$\Delta kW = \Delta kWh / FLHcool * CF$

Where:

FLHcool = *Full Load Cooling Hours*

= *Dependent on location as below:*

Location	FLHcool
Wilmington, DE	*513* [261]
Baltimore, MD	*531* [262]
Washington, DC	*668*

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*

= *0.69* [263]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*

= *0.66* [264]

For example, insulating 1200 square feet of attic from R-5 to R-30 in a home with a 12 SEER central Air Conditioning unit in Baltimore, MD.

$\Delta kW = 120 / 531 * 0.69$

$= 0.16 \text{ kW}$

Annual Fossil Fuel Savings Algorithm

$\Delta MMBTU = ((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat$

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[261] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

262 Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[263] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

[264] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the PJM Peak Definition coincidence factor is 0.66.

Where:

HDD = Heating Degree Days

= dependent on location[265]

Location	*Heating Degree Days (60°F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

*ηHeat = Efficiency of Heating equipment (equipment efficiency * distribution efficiency)*

= actual[266]*. If not available use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[267]*.*

For example, insulating 1200 square feet of attic from R-5 to R-30 in a home with a 75% efficiency heating system in Baltimore, MD.

$$\Delta MMBtu = ((1/5 - 1/30) * 3457 * 24 * 1{,}200) / 1{,}000{,}000 / 0.75$$

$$= 22\ MMBtu$$

Annual Water Savings Algorithm

n/a

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[265] The 10 year average annual heating degree day value is calculated for a number of locations, using a balance point for heating equipment use of 60 degrees (based on data obtained from http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm). The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

[266] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.

[267] The equipment efficiency default is based on data provided by GAMA during the Federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%. The distribution efficiency default is based on assumption that 50% of duct work is inside the envelope, with some leaks and no insulation. VEIC did not have any more specific data to provide any additional defaults.

Incremental Cost

The incremental cost for this measure should be the actual installation and labor cost to perform the insulation work.

Measure Life

The measure life is assumed to be 25 years[268].

Operation and Maintenance Impacts

n/a

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[268] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Efficient Windows - Energy Star Time of sale

Unique Measure Code(s): RS_SL_TOS_WINDOW_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure describes the purchase of Energy Star Windows (u-0.32; SHGC-0.40 minimum requirement for North Central region) at natural time of replacement or new construction outside of the Energy Star Homes program. This does not relate to a window retrofit program. Measure characterization assumes electric heat- either resistance or heat pump.

Definition of Baseline Condition

The baseline condition is a standard double pane window with vinyl sash, (u- 0.49 SHGC-0.58).

Definition of Efficient Condition

The efficient condition is an ENERGY STAR window (u-0.32; SHGC-0.40 minimum requirement for North Central region).

Annual Energy Savings Algorithm [269]

Heating kWh Savings (Electric Resistance) = 356 kWh per 100 square feet window area

Heating kWh Savings (Heat Pump COP 2.0) = 194 kWh per 100 square feet window area

Cooling kWh Savings (SEER 10) = 205 kWh per 100 square feet window area

Summer Coincident Peak kW Savings Algorithm

$$\Delta kWcooling = \Delta kWREM * CF$$

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[269] Based on REMRate modeling of New Jersey baseline existing home moved to Baltimore climate with electric furnace or air source heat pump HSPF 2.0, SEER 10 AC. Ducts installed in un-conditioned basement. Duct leakage set at RESNET/HERS qualitative default.

Where:

$\Delta kWREM$ = Delta kW calculated in REMRate model
= 0.12 kW per 100 square feet window area

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69 [270]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.66 [271]

ΔkW_{SSP} cooling = 0.12 * 0.69

= 0.083 kW per 100 square feet of windows

ΔkW_{PJM} cooling = 0.12 * 0.66

= 0.079 kW per 100 square feet of windows

Annual Fossil Fuel Savings Algorithm

n/a for homes with electric heat.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $150 per 100 square feet of windows.[272]

Measure Life

The measure life is assumed to be 25 years.[273]

Operation and Maintenance Impacts

n/a

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[270] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

[271] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the PJM Peak Definition coincidence factor is 0.66.

[272] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007.

[273] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Pool Pump End Use

Pool pump-two speed

Unique Measure Code: RS_PP_TOS_PPTWO_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes the purchase of a two speed swimming pool pump capable of running at 50% speed and being run twice as many hours to move the same amount of water through the filter. The measure could be installed in either an existing or new swimming pool. The installation is assumed to occur during a natural time of sale.

Definition of Baseline Condition

The baseline condition is a standard efficiency, 1.36 kW electric pump operating 5.18 hours per day.

Definition of Efficient Condition

The efficient condition is an identically sized two speed pump operating at 50% speed (50% flow) for 10.36 hours per day.

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{Base} - kWh_{Two\ Speed}$$ [274]

Where:

kWh_{Base} = *typical consumption of a single speed motor in a cool climate (assumes 100 day pool season)*
= *707 kWh*

$kWh_{Two\ Speed}$ = *typical consumption for an efficient two speed pump motor*
= *177 kWh*

$$\Delta kWh = 707 - 177$$

---

[274] Based on INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR RESIDENTIAL POOL PUMPS, SCE Design & Engineering; Phase1: Demand Response Potential DR 09.05.10 Report

$= 530$ kWh

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$$ [275]

Where:

kW_{Base} = *Connected load of baseline motor*
= *1.3 kW*

$kW_{Two\ Speed}$ = *Connected load of two speed motor*
= *0.171 kW*

CF_{SSP} = *Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)*
= *0.20*[276]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for pool pumps (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.27*[277]

$$\Delta kW_{SSP} = (1.3-0.171) * 0.20$$

$$= 0.23 \text{ kW}$$

$$\Delta kW_{SSP} = (1.3-0.171) * 0.27$$

$$= 0.31 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

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[275] All factors are based on data from INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR RESIDENTIAL POOL PUMPS, SCE Design & Engineering; Phase1: Demand Response Potential DR 09.05.10 Report

[276] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[277] Ibid.

Incremental Cost

The incremental cost for this measure is assumed to be $175 for a two speed pool pump motor[278].

Measure Life

The measure life is assumed to be 10 yrs[279].

Operation and Maintenance Impacts

n/a

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[278] Based on review of Lockheed Martin pump retail price data, July 2009.

[279] VEIC estimate.

Pool pump-variable speed

Unique Measure Code: RS_PP_TOS_PPVAR_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes the purchase of a variable speed swimming pool pump capable of running at 40% speed and being run two and a half times as many hours to move the same amount of water through the filter. The measure could be installed in either an existing or new swimming pool. The installation is assumed to occur during a natural time of sale.

Definition of Baseline Condition

The baseline condition is a standard efficiency, 1.36 kW electric pump operating 5.18 hours per day.

Definition of Efficient Condition

The efficient condition is an identically sized two speed pump operating at 40% speed (50% flow) for 13 hours per day.

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{Base} - kWh_{Variable\ Speed}$$ [280]

Where:

kWh_{Base} = *typical consumption of a single speed motor in a cool climate (assumes 100 day pool season)*
= 707 kWh

$kWh_{Variable\ Speed}$ = *typical consumption for an efficient variable speed pump motor*
= 113 kWh

$$\Delta kWh = 707 - 113$$

---

[280] Based on INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR RESIDENTIAL POOL PUMPS, SCE Design & Engineering; Phase1: Demand Response Potential DR 09.05.10 Report

= 594 kWh

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$$ [281]

Where:

kW_{Base} = *Connected load of baseline motor*
= *1.3 kW*
$kW_{Two\ Speed}$ = *Connected load of two speed motor*
= *0.087 kW*
CF_{SSP} = *Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)*
= *0.20*[282]
CF_{PJM} = *PJM Summer Peak Coincidence Factor for pool pumps (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.27*[283]

$$\Delta kW_{SSP} = (1.3\text{-}0.087) * 0.20$$

$$= 0.24 \text{ kW}$$

$$\Delta kW_{SSP} = (1.3\text{-}0.\ 087) * 0.27$$

$$= 0.34 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

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[281] All factors are based on data from INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR RESIDENTIAL POOL PUMPS, SCE Design & Engineering; Phase1: Demand Response Potential DR 09.05.10 Report

[282] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[283] Ibid.

Incremental Cost

The incremental cost for this measure is assumed to be $750 for a variable speed pool pump motor[284].

Measure Life

The measure life is assumed to be 10 yrs[285].

Operation and Maintenance Impacts

n/a

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[284] Based on review of Lockheed Martin pump retail price data, July 2009.

[285] VEIC estimate.

Plug Load End Use

"Smart-Strip" plug outlets

Unique Measure Code: RS_PL_TOS_SMARTS_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes savings associated with the purchase and use of a Controlled Power Strip (or Smart Strips). These multi-plug power strips have the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced.

This measure characterization provides savings for a 5-plug strip and a 7-plug strip.

Definition of Baseline Condition

The assumed baseline is a standard power strip that does not control any of the connected loads.

Definition of Efficient Condition

The efficient case is the use of a 5 or 7-plug smart strip.

Annual Energy Savings Algorithm

$$\Delta kWh_{5\text{-Plug}} = 56.5 \text{ kWh}$$
$$\Delta kWh_{7\text{-Plug}} = 102.8 \text{ kWh}$$ [286]

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[286] NYSERDA Measure Characterization for Advanced Power Strips. Study based on review of:
i) Smart Strip Electrical Savings and Usability, Power Smart Engineering, October 27, 2008.
ii) Final Field Research Report, Ecos Consulting, October 31, 2006. Prepared for California Energy Commission's PIER Program.
iii) Developing and Testing Low Power Mode Measurement Methods, Lawrence Berkeley National Laboratory (LBNL), September 2004. Prepared for California Energy Commission's Public Interest Energy Research (PIER) Program.
iv) 2005 Intrusive Residential Standby Survey Report, Energy Efficient Strategies, March, 2006.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / Hours * CF$$

Where:

Hours = *Annual hours when controlled standby loads are turned off*

= *7,149*[287]

CF = *Coincidence Factor*

= *0.8*[288]

$$\Delta kW_{5\text{-Plug}} = (56.5/7{,}149) * 0.8 = 0.0063 \text{ kW}$$

$$\Delta kW_{5\text{-Plug}} = (102.8/7{,}149) * 0.8 = 0.012 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $16 for a 5-plug and $26 for a 7-plug[289].

Measure Life

The measure life is assumed to be 4 years[290].

Operation and Maintenance Impacts

n/a

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v) Smart Strip Portfolio of the Future, Navigant Consulting for San Diego G&E, March 31, 2009.

[287] Average of off hours for controlled TV and computer from above study.

[288] In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.

[289] NYSERDA Measure Characterization for Advanced Power Strips

[290] David Rogers, Power Smart Engineering, October 2008: "Smart Strip electrical savings and usability", p22. Assumes that the unit can only take one surge and then needs to be replaced.

COMMERCIAL & INDUSTRIAL MARKET SECTOR

Lighting End Use

CFL - Screw base, Retail - Commercial

Unique Measure Code(s): CI_LT_TOS_CFLSCR_V1.0510
Effective Date: May 2010
End Date:

Measure Description

A compact fluorescent light bulb (CFL) is purchased in retail and installed in a commercial location. The incremental cost of the CFL compared to an incandescent light bulb is offset via either rebate coupons or via upstream markdowns.

Definition of Baseline Condition

The baseline is the purchase and installation of an incandescent light bulb.

Definition of Efficient Condition

The efficient condition is the purchase and installation of a compact fluorescent light bulb.

Annual Energy Savings Algorithm

$$\Delta kWh = (\Delta Watts / 1000) \times HOURS \times ISR \times WHFe$$

Where:

ΔWatts = *Compact Fluorescent Watts (if known) * 2.95* [291]

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from

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[291] The average wattage of the replacement CFL is 61.2W, and the average wattage of existing incandescent lamp is 15.5W. Thus, ΔWatts = [WattsEE * (WattsBASE_RLW/WattsEE_RLW)] - WattsEE = WattsEE * (3.95 - 1) = WattsEE * 2.95.:
RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

the Energy Independence and Security Act of 2007 discussed below:

CFL Wattage	Delta Watts Multiplier[292]			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	2.95	2.95	2.95	1.83
16-20	2.95	2.95	1.79	1.79
21W+	2.95	1.84	1.84	1.84

If Compact Fluorescent Watts is unknown use 45.7W [293]

Note: The delta watts should be adjusted to 30.1[294] from 2013 onwards to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below.

HOURS = *Average hours of use per year*
= *If annual operating hours are unknown, see table "Interior CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information.*[295]

ISR = *In Service Rate or percentage of units rebated that get installed = 0.95* [296]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
= *1.13* [297]

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[292] Calculated by finding the new delta watts after incandescent bulb wattage is reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014); see MidAtlantic CFL Adjustments.xls.

[293] RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

[294] Calculated by multiplying 48.7 by the average adjustment 2014 percentage adjustment from table below. This adjustment should be made in 2013 since this is the midpoint of the 3 EISA adjustment years. See MidAtlantic CFL Adjustments.xls for calculation.

[295] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

[296] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

For example:, assuming an office building:

$$\Delta kWh = (45.7 / 1000) \times 2{,}478 \times 0.95 \times 1.13$$

$$= 121.6 \text{ kWh}$$

Interior CFL Lighting Operating Hours and Coincidence Factors by Building Type[298]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,395	0.76	0.76
Schools	1,670	0.41	0.44
Grocery/Supermarket	3,879	0.87	0.87
Health	1,888	0.43	0.43
Hospital	4,081	0.80	0.80
Lodging - Common Area	3,984	0.43	0.43
Lodging - Guest Rooms	766	0.09	0.09
Manufacturing	1,268	0.34	0.30
Office	2,478	0.43	0.45
Other/Misc.	1,871	0.33	0.34
Restaurant	3,765	0.62	0.62
Retail	3,043	0.60	0.61
Warehouse	2,063	0.58	0.69

Note: CF_{PJM} refers to the PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm). CF_{SSP} refers to Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

Baseline Adjustment

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[297] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[298] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification". CFPJM refers to the

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[299]:

CFL Wattage	Savings as Percentage of Base Year Savings			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	100%	100%	100%	62%
16-20	100%	100%	61%	61%
21W+	100%	63%	63%	63%

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta Watts\ /1000) \times ISR \times WHFd \times CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*

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[299] Calculated by finding the percentage reduction in delta watts, for example for a 100W bulb: (72-25.3)/(100-25.3) = 62.5%. See MidAtlantic CFL Adjustments.xls for calculation.

= *1.25* [300]

CF = *Summer Peak Coincidence Factor for measure*
= *See table "Interior CFL Lighting Operating Hours and Coincidence Factors by Building Type" above*

For example, assuming an office building:

$\Delta kW = (45.7 / 1000) * 0.95 * 1.25 * 0.45$

$= 0.024\ kW$

Note: The savings adjustment due to the shifting baseline documented above should be applied to the peak kW savings assumed in the later years.

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$\Delta MMBTU = (-\Delta kWh / WHFe) \times 0.70 \times 0.003413 \times 0.23 / 0.75$
$= -\Delta kWh \times 0.00065$

Where:

0.7 = *Aspect ratio* [301]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [302]
0.75 = *Assumed heating system efficiency* [303]

For example, assuming an office building:

$\Delta MMBTU = (-121.6 / 1.13) * 0.7 * 0.003413 * 0.23 / 0.75$

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[300] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[301] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[302] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[303] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

$$= -0.079 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $3.[304]

Measure Life

The measure life is assumed to be 3.4 years.[305]

Operation and Maintenance Impacts

In order to account for the shift in baseline due to the Federal Legislation discussed above, the levelized baseline replacement cost over the lifetime of the CFL is calculated (see MidAtlantic CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

	Standard Incandescent	Efficient Incandescent
Replacement Cost	$0.50	$2.00
Component Life (years) (based on lamp life / assumed annual run hours)	0.29[306]	1[307]

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[304] Based on review of TRM assumptions for other States.

[305] Conservative assumption based on a typical equipment lifetime of 12,000 hours and average daily usage of 9.6 hours.

[306] Assumes rated life of incandescent bulb of 1000 hours and assumes 3,500 run hours.

[307] VEIC best estimate of future technology.

High Performance and Reduced Wattage T8 Lighting Equipment

Unique Measure Code(s): CI_LT_TOS_HPT8_V1.0510 and CI_LT_RTR_HPT8_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure promotes the installation of High-Performance T8 (HPT8) or Reduced Wattage (RWT8) 4-ft lamp/ballast systems that have higher lumens per watt than standard 4-ft T8 systems. This results in lamp/ballast systems that produce equal or greater light than standard T8 systems, while using fewer watts. The Consortium for Energy Efficiency (CEE) maintains specifications and a list for qualifying High Performance and Reduced Wattage T8 lamps and ballasts. The list is updated frequently and is available at http://www.cee1.org/com/com-lt/com-lt-main.php3.

For lost opportunity scenarios (i.e. time of replacement) this measures assumes that a HPT8 or RWT8 fixture is installed instead of a standard performance 4-ft T8 fixture. For retrofit situations, it is assumed that the lamp(s) and ballast(s) in an existing 4-ft T12 fixture are replaced with qualifying HPT8 or RWT8 components.

Two-foot and 3-ft T8 advanced T8 systems can similarly replace standard-performance 2-ft and 3-ft T8 or T12 systems. Although 2-ft and 3-ft lamps are not listed on the CEE website, the same qualifying ballasts listed on the website that are used for 4-ft lamps should be selected for the 2-ft and 3-ft lamps.

Definition of Baseline Condition

The baseline condition is assumed to be the existing lighting fixture in retrofit applications. For lost-opportunity applications, the baseline condition will vary depending upon the specific characteristics of the fixtures installed (e.g. number of lamps) and any applicable codes and standards in the region. For illustrative purposes the following baseline conditions are assumed:

Lost-opportunity: a 3-lamp standard performance 4-ft F32 T8 fixture with electronic ballast with an input wattage of 89W.

Retrofit: a 3-lamp 4-ft F34 T12 fixture with magnetic ballast with an input wattage of 136W.

Definition of Efficient Condition

The efficient conditions for the lost-opportunity and retrofit applications are a qualifying High Performance T8 fixture and lamp/ballast combination, respectively. For illustrative purposes the following high efficiency conditions for the corresponding baselines are assumed:

Lost-opportunity: a 3-lamp High Performance T8 fixture with electronic ballast with an input wattage of 72W.

Retrofit: relamp / reballast with qualifying lamps and ballast with resulting fixture input wattage of 72W.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) \times HOURS \times ISR \times WHFe$$

Where:

WattsBASE = Connected load of baseline fixture (for "Time of Sale" or "Replacement on Burnout" measures)

Or = Connected load of existing fixture (for "Retrofit" measures)

WattsEE = Connected load of HPT8 fixture

HOURS = Average hours of use per year

= If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information.[308]

ISR = In Service Rate or percentage of units rebated that get installed = 0.97[309]

WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.

= 1.13[310]

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[308] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

[309] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

[310] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

For example, assuming an office installation:

Lost opportunity:

$$\Delta kWh = ((89 - 72) / 1000) * 2{,}567 * 0.97 * 1.13$$

$$= 47.8 \text{ kWh per fixture}$$

Retrofit:

$$\Delta kWh = ((136 - 72) / 1000) * 2{,}567 * 0.97 * 1.13$$

$$= 180.1 \text{ kWh per fixture}$$

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[311]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging - Common Area	7,884	0.90	0.90
Lodging - Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

Note: CF_{PJM} refers to the PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm). CF_{SSP} refers to Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

Summer Coincident Peak kW Savings Algorithm

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[311] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

ΔkW = ((WattsBASE – WattsEE) / 1000) x ISR x WHFd x CF

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting
= 1.25 [312]
CF = Summer Peak Coincidence Factor for measure
= See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)

For example, assuming an office installation:

Lost opportunity:
ΔkW = ((89 - 72) / 1000) * 0.97 * 1.25 * 0.60

= 0.012 kW per fixture

Retrofit:
ΔkW = ((136 – 72) / 1000) * 0.97 * 1.25 * 0.60

= 0.047 kW per fixture

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) x 0.70 x 0.003413 x 0.23 / 0.75

= -ΔkWh x 0.00065

Where:

0.7 = Aspect ratio [313]
0.003413 = Constant to convert kWh to MMBTU

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[312] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[313] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

0.23 = *Fraction of lighting heat that contributes to space heating*[314]

0.75 = *Assumed heating system efficiency*[315]

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs will vary by specific equipment installed. The incremental costs for the example measures are assumed to be $25 for lost opportunity and $60 for retrofit.[316]

Measure Life

The measure life is assumed to be 15 years. ("Time of Sales" or "Replacement on Burnout" measures) and 6 years ("Retrofit" measures).[317]

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of replacement lamps and ballasts between the efficient and baseline cases, there are significant operation and maintenance impacts associated with this measure. Actual operation and maintenance costs will vary by specific equipment installed/replaced. For the selected examples:

Lost opportunity:	$-0.40 / year[318]
Retrofit:	$2.50 / year[319]

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[314] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[315] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[316] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[317] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf. On June 26, 2009, U.S. Department of Energy issued a final rule amending the energy conservation standards for general service fluorescent lamps. The standards established in the final rule will be applied starting July 14, 2012. These standards essentially require that certain linear fluorescent lamp types meet High Performance T8 specifications. For some equipment types, baseline lamps will become unavailable and participants will be required to upgrade both lamps and ballasts to High Performance T8s, thus negating any savings. Assuming a typical lamp has a lifetime of 18,000 hours and is operated approximately 3,300 hours per year, new lamps installed shortly before the impending federal standards take effect will need to be replaced in early-2017, indicating that savings should be claimed for only 6 years for measures installed in 2011.

[318] Negative value indicates cost increase.

[319] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

T5 Lighting

Unique Measure Code(s): CI_LT_TOS_T5_V1.0510 and CI_LT_RTR_T5_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure describes the installation of high-bay T5 lamp/ballast systems.

Definition of Baseline Condition

The baseline condition is a metal-halide fixture.

Definition of Efficient Condition

The efficient condition is a four Lamp T5 High Output fixture.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) \times HOURS \times ISR \times WHFe$$

Where:

WattsBASE = Actual Connected load of baseline fixture
WattsEE = Actual Connected load of Metal Halide fixture
HOURS = Average hours of use per year
= If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information. [320]
ISR = In Service Rate or percentage of units rebated that get installed = 0.97 [321]

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[320] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

[321] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
= *1.13*[322]

For example, a 240W T5 fixture installed in place of a 455W metal-halide in a warehouse:

$$\Delta kWh = ((455 - 240) / 1000) * 2316 * 0.97 * 1.13$$

$$= 545.8 \text{ kWh}$$

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[323]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging - Common Area	7,884	0.90	0.90
Lodging - Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

Note: CF_{PJM} refers to the PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm). CF_{SSP} refers to Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

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[322] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[323] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) \times ISR \times WHFd \times CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.25* [324]

CF = *Summer Peak Coincidence Factor for measure*
= *See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)*

For example:, a 240W T5 fixture installed in place of a 455W metal-halide in a warehouse:

$$\Delta kW = ((455 - 240) / 1000) * 0.97 * 1.25 * 0.55$$

$$= 0.14 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) \times 0.70 \times 0.003413 \times 0.23 / 0.75$$
$$= -\Delta kWh \times 0.00065$$

Where:

0.7 = *Aspect ratio* [325]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [326]
0.75 = *Assumed heating system efficiency* [327]

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[324] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floor space in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[325] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[326] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

For example:

$$\Delta MMBTU = (-545.8 / 1.13) * 0.7 * 0.003413 * 0.23 / 0.75$$

$$= -0.35 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $300.[328]

Measure Life

The measure life is assumed to be 15 years.[329]

Operation and Maintenance Impacts

n/a

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[327] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[328] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[329] 'Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Pulse-Start Metal Halide fixture - interior

Unique Measure Code(s): CI_LT_TOS_MHFIN_V1.0510 and CI_LT_RTR_MHFIN_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure documents the electricity impacts for the installation of a high efficiency pulse-start metal halide fixture in an interior space.

Definition of Baseline Condition

The baseline condition is a mercury vapor fixture. For illustrative purposes, a 205W mercury vapor fixture (~175W lamp wattage) is assumed.

Definition of Efficient Condition

The efficient condition is a pulse-start metal halide fixture. For illustrative purposes, an 118W pulse-start metal halide fixture (~100W lamp wattage) is assumed.

Annual Energy Savings Algorithm

$$\Delta kWh = (WattsBASE - WattsEE) / 1000 \times HOURS \times ISR \times WHFe$$

Where:

WattsBASE = Connected load of baseline fixture
= Actual installed
WattsEE = Connected load of Metal Halide fixture
= Actual installed
HOURS = Average hours of use per year
= If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information.[330]

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[330] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

ISR = *In Service Rate or percentage of units rebated that get installed = 0.97* [331]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
13 [332]

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[333]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging - Common Area	7,884	0.90	0.90
Lodging - Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

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[331] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010Based on the in-service rate negotiated between Efficiency Vermont and the Vermont Department of Public Service; Mid-Atlantic specific value should be determined with subsequent evaluations.

[332] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.11 13 (calculated as 1 + (0.6374*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 6374% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995derived from Commercial Buildings Energy Consumption Survey 2003 data) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[333] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

Note: CF_{PJM} refers to the PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm). CF_{SSP} refers to Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE)\ /1000) \times ISR \times WHFd \times CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.25* [334]

CF = *Summer Peak Coincidence Factor for measure*
= *See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)*

For example, assuming a warehouse installation:

$$\Delta kW = ((205 - 118)\ /\ 1000) * 0.97 * 1.25 * 0.55$$

$$= 0.06 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh\ /\ WHFe) \times 0.70 \times 0.003413 \times 0.23\ /\ 0.75$$
$$= -\Delta kWh \times 0.00065$$

Where:

0.7 = *Aspect ratio* [335]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [336]

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[334] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[335] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

0.75 = *Assumed heating system efficiency*[337]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $37.5.[338]

Measure Life

The measure life is assumed to be 15 years.[339]

Operation and Maintenance Impacts

n/a

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[336] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[337] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[338] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[339] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Pulse Start Metal Halide - exterior

Unique Measure Code(s): CI_LT_TOS_MHFEX_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the installation of a pulse start metal halide in place of a standard metal halide in an exterior setting. This could relate to a time of replacement or retrofit situation.

Definition of Baseline Condition

The baseline condition is defined as a standard metal halide.

Definition of Efficient Condition

The efficient condition is defined as a pulse start metal halide.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) \ / \ 1000) \times HOURS \times ISR$$

Where:

WattsBASE = Actual Connected load of baseline fixture
WattsEE = Actual Connected load of pulse start metal halide fixture
HOURS = Average hours of use per year
= If annual operating hours are unknown, assume 3,338 [340]. *Otherwise*[341]*, use site specific annual operating hours information.*
ISR = In Service Rate or percentage of units rebated that get installed = 0.97 [342]

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[340] Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[341] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

[342] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

For example, a 365W pulse start metal halide fixture is installed in place of a 455W standard metal halide:

$$\Delta kWh = ((455 - 365) / 1000) * 3{,}338 * 0.97$$

$$= 291.4 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) \times ISR \times CF$$

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.037 [343]

For example:

$$\Delta kW = ((455 - 365) / 1000) * 0.97 * 0.037$$

$$= 0.003 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $37.50.[344]

Measure Life

The measure life is assumed to be 15 years.[345]

Operation and Maintenance Impacts

n/a

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[343] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[344] Ibid.

[345] 'Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

High Pressure Sodium

Unique Measure Code(s): CI_LT_TOS_SODIUM_V1.0510 and CI_LT_RTR_SODIUM_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the installation of a High Pressure Sodium fixture in an exterior location.

Definition of Baseline Condition

The baseline condition is a quartz halogen lamp.

Definition of Efficient Condition

The efficient condition is a high-pressure sodium lamp.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) \times HOURS \times ISR$$

Where:

WattsBASE = Actual Connected load of baseline fixture
WattsEE = Actual Connected load of HPT8 fixture
HOURS = Average hours of use per year
= If annual operating hours are unknown, assume 3,338 [346]. *Otherwise, use site specific annual operating hours information.* [347]
ISR = In Service Rate or percentage of units rebated that get installed = 0.97 [348]

---

[346] Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[347] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

[348] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

For example, a 90W high pressure sodium lamp installed in place of a 200W quartz halogen lamp:

$$\Delta kWh = ((200 - 90) / 1000) * 3{,}338 * 0.97$$

$$= 356.1 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) \times ISR \times CF$$

Where:

CF = *Summer Peak Coincidence Factor for measure* = *0.0374* [349]

For example:

$$\Delta kW = ((200 - 90) / 1000) * 0.97 * 0.0374$$

$$= 0.0040 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $30.[350]

Measure Life

The measure life is assumed to be 15 years.[351]

Operation and Maintenance Impacts

n/a

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[349] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[350] Ibid.

[351] 'Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

LED Exit Sign

Unique Measure Code(s): CI_LT_RTR_LEDEXI_V1.0510
Effective Date: May 2010
End Date:

Measure Description

This measure relates to the installation of an exit sign illuminated with light emitting diodes (LED). This measure should be limited to retrofit installations.

Definition of Baseline Condition

The baseline condition is an exit sign with a non-LED light-source.

Definition of Efficient Condition

The efficient condition is an exit sign illuminated with light emitting diodes (LED).

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) \times HOURS \times ISR \times WHFe$$

Where:

WattsBASE = Actual Connected load of existing exit sign. If connected load of existing exit sign is unknown, assume 16 W.[352]
WattsEE = Actual Connected load of LED exit sign
HOURS = Average hours of use per year
= 8,760[353]
ISR = In Service Rate or percentage of units rebated that get installed = 0.97[354]
WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.
= 1.13[355]

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[352] Assumes a fluorescent illuminated exit sign. Wattage consistent with ENERGY STAR assumptions. See http://www.energystar.gov/ia/business/small_business/led_exitsigns_techsheet.pdf.

[353] Assumes operation 24 hours per day, 365 days per year.

[354] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

For example a 5W LED lamp in place of a 16W CFL:

$$\Delta kWh = ((16 - 5) / 1000) * 8{,}760 * 0.97 * 1.13$$

$$= 105.6 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (WattsBASE - WattsEE) / 1000 \times ISR \times WHFd \times CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.25* [356]

CF = *Summer Peak Coincidence Factor for measure*
= *1.0* [357]

For example:

$$\Delta kW = ((16 - 5) / 1000) * 0.97 * 1.25 * 1.0$$

$$= 0.013 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) \times 0.70 \times 0.003413 \times 0.23 / 0.75$$
$$= -\Delta kWh \times 0.00065$$

---

[355] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[356] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[357] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

Where:

0.7 = Aspect ratio [358]
0.003413 = Constant to convert kWh to MMBTU
0.23 = Fraction of lighting heat that contributes to space heating [359]
0.75 = Assumed heating system efficiency [360]

For example:

ΔMMBTU = (-105.6/ 1.13) * 0.7 * 0.003413 * 0.23 / 0.75

= -0.069 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $35.[361]

Measure Life

The measure life is assumed to be 7 years.[362]

Operation and Maintenance Impacts

n/a

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[358] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[359] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[360] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[361] Represents the full installed cost of an LED exit sign. LED exit signs can typically be purchased for ~$25 (see http://www.exitlightco.com/Exit_Signs and "http://www.simplyexitsigns.com"). Assuming replacing exit sign requires 15 minutes of a common building laborer's time in Washington D.C. (RSMeans Electrical Cost Data 2008), the total installed cost would be approximately $35.

[362] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf. Measure life in source study is reduced by ~50% assuming existing equipment is at one half of its useful life.

Solid State Lighting (LED) Recessed Downlight

Unique Measure Code: CI_LT_TOS_SSLDWN_V2.0711, CI_LT_RTR_SSLDWN_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure relates to the installation of an ENERGY STAR v1.3 qualified commercial LED recessed downlight in place of a standard efficiency lighting technology[363]. This measure could be either a lost-opportunity or retrofit installation.

Definition of Baseline Condition

The baseline condition is a standard efficiency downlight technology such as incandescent, compact fluorescent, or metal halide.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR v1.3 qualified commercial LED recessed downlight listed on the ENERGY STAR Qualified LED Lighting list[364].

Annual Energy Savings Algorithm

For **lost-opportunity** installations:

$$\Delta kWh = [(WattsEE * (WattsBASE_{typ}/WattsEE_{typ}) - WattsEE) / 1000] * ISR * HOURS * WHF_e$$

$$= [((WattsEE * 3.08) - WattsEE) / 1000] * ISR * HOURS * WHF_e$$

For **retrofit** installations:

$$\Delta kWh = [(WattsBASE - WattsEE) / 1000] * ISR * HOURS * WHF_e$$

Where:

WattsEE = *Connected load of LED recessed downlight*
= *Actual Installed [W]*
$WattsBASE_{typ}$ = *typical baseline wattage; assumed as 54.8W*[365]

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[363] See http://www.energystar.gov/ia/partners/product_specs/program_reqs/Solid-State_Lighting_Program_Requirements.pdf

[364] The list can be found here: http://www.energystar.gov/index.cfm?fuseaction=ssl.display_products_com_pdf

[365] Based on 2008-2010 Efficiency Vermont historical data of 835 installed measures

WattsEE

$WattsEE_{typ}$ = *typical wattage of the LED recessed downlight; assumed as 17.8W*[366]

WattsBASE = *Connected load of the baseline light fixture*
= *Actual Installed [W]*

ISR = *0.97*[367]

HOURS = *Average hours of use per year*
= *If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information*[368].

WHF_e = *Waste heat factor(energy) to account for space cooling energy saving due to the generation of reduced lighting waste heat.*
= *1.13*[369]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = [(WattsBASE - WattsEE) / 1,000] \times ISR \times WHF_d \times CF$$

Where:

WHF_d = *Waste heat factor(demand) to account for space cooling demand saving due to the generation of reduced lighting waste heat.*
= *1.25*[370]

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[366] Based on 2008-2010 Efficiency Vermont historical data of 835 installed measures

[367] "Verification of Reported Energy and Peak Savings from the EmPOWER Maryland Energy Efficiency Programs," Itron, Inc., March 2011.

[368] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

[369] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[370] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of

CF = *Summer Peak Coincidence Factor for measure*
= *See "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" table in the "Reference Tables" section.*

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (-\Delta kWh\ /\ WHFe) \times Aspect\ Ratio \times 0.003413 \times Heating\ Fraction\ /\ \eta_{Heat}$$

$$= -\Delta kWh \times 0.00065$$

Where:

Aspect Ratio = *0.70*[371]
0.003413 = *MMBtu/kWh unit conversion factor*
Heating Fraction (lighting heat that contributes to space heating) = *0.23*[372]
η_{Heat} = *0.75*[373]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $80[374] for lost-opportunity installations. Custom incremental costs should be calculated for retrofit installations.

Measure Life

The measure life is assumed to be 10 years[375].

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lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[371] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

[372] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[373] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[374] Efficiency Vermont Technical Reference User Manual No. 2010-67a

[375] The ENERGY STAR specification for solid state recessed downlights requires luminaires to maintain >=70% initial light output for 35,000 hours in a commercial application. Measure life is therefore assumed to be 10 years (calculated as 35,000 hours divided by an approximate 3,500 annual operating hours).

Operation and Maintenance Impacts

There are significant operation and maintenance savings associated with this measure. If the actual existing or baseline system component costs are unknown, use the following composite baseline component assumptions to calculate the O&M impacts[376]:

Assume 40% 26W Compact Fluorescent System

Lamp Life (hours):	10,000
Lamp Cost:	$9.70
Lamp Rep. Labor Cost:	$2.67
Lamp Rep. Recycle Cost:	$0.25
Ballast Life (hours):	40,000
Ballast Cost:	$16.00
Ballast Rep. Labor Cost:	$25.00
Ballast Rep. Disposal Cost:	$5.00

Assumed 60% Halogen PAR30/38

Lamp Life (hours):	2,500
Lamp Cost:	$10.00
Lamp Rep. Labor Cost:	$2.67

The calculated net present value of the baseline replacement costs is $93.45.

Reference Tables

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[377]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80

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[376] Efficiency Vermont Technical Reference User Manual No. 2010-67a

[377] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

Building Type	HOURS	CF_{PJM}	CF_{SSP}
Lodging - Common Area	7,884	0.90	0.90
Lodging - Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

Note: CF_{PJM} refers to the PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm). CF_{SSP} refers to Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

Delamping

Unique Measure Code(s): CI_LT_ERT_DELAMP_V1.0510
Effective Date: May 2010
End Date:

Measure Description

This measure relates to the permanent removal of a lamp and the associated electrical sockets (or "tombstones") from a fixture.

Definition of Baseline Condition

The baseline conditions will vary dependent upon the characteristics of the existing fixture. For illustrative purposes, a baseline three lamp 4ft T8 Fixture with input wattage of 89W is assumed.

Definition of Efficient Condition

The efficient condition will vary depending on the existing fixture and the number of lamps removed. For illustrative purposes, a two lamp 4ft T8 Fixture on a three lamp ballast (67W) is assumed.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) \ / \ 1000) \times HOURS \times WHFe$$

Where:

WattsBASE = *Actual Connected load of baseline fixture*
WattsEE = *Actual Connected load of delamped fixture*
HOURS = *Average hours of use per year*
= *If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information.* [378]
WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*

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[378] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

= *1.13* [379]

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[380]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging - Common Area	7,884	0.90	0.90
Lodging - Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

Note: CF_{PJM} refers to the PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm). CF_{SSP} refers to Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) \times WHFd \times CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.25* [381]

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[379] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[380] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

CF = *Summer Peak Coincidence Factor for measure*
= *See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)*

For example, one lamp of a three lamp 4ft T8 Fixture (89W) is removed (leaving 67W) in an office:

$$\Delta kW = ((89 - 67) / 1000) * 1.25 * 0.60$$

$$= 0.017 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) \times 0.70 \times 0.003413 \times 0.23 / 0.75$$
$$= -\Delta kWh \times 0.00065$$

Where:

0.7 = *Aspect ratio* [382]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [383]

0.75 = *Assumed heating system efficiency* [384]

Annual Water Savings Algorithm

n/a

Incremental Cost

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[381] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[382] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[383] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[384] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

The incremental cost for this measure is assumed to be $10.8 per fixture.[385]

Measure Life

The measure life is assumed to be 15 years.[386]

Operation and Maintenance Impacts

Delamping reduces the number of periodic lamp replacements required, saving $1.25/year.

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[385] Assumes delamping a single fixture requires 15 minutes of a common building laborer's time in Washington D.C.; Adapted from RSMeans Electrical Cost Data 2008.

[386] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Occupancy Sensor - Wall box

Unique Measure Code(s): CI_LT_TOS_OSWALL_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure defines the savings associated with installing a wall mounted occupancy sensor that switches lights off after a brief delay when it does not detect occupancy.

Definition of Baseline Condition

The baseline condition is lighting that is not controlled with an occupancy sensor.

Definition of Efficient Condition

The efficient condition is lighting that is controlled with an occupancy sensor.

Annual Energy Savings Algorithm

$$\Delta kWh = kWconnected \times HOURS \times SVG \times ISR \times WHFe$$

Where:

kWconnected= Assumed kW lighting load connected to control.
HOURS = Average hours of use per year before control
= If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours. [387]
SVG = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.

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[387] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

= *0.3* [388]

ISR = *In Service Rate or percentage of units rebated that get installed = 0.98* [389]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*

= *1.13* [390]

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[391]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging - Common Area	7,884	0.90	0.90
Lodging - Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

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[388] Quantum Consulting, Inc., for Pacific Gas & Electric Company, Evaluation of Pacific Gas & Electric Company's 1997 Commercial Energy Efficiency Incentives Program: Lighting Technologies, March 1, 1999.

[389] Based on the in-service rate negotiated between Efficiency Vermont and the Vermont Department of Public Service; Mid-Atlantic specific value should be determined with subsequent evaluations.

[390] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[391] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

Note: CF_{PJM} refers to the PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm). CF_{SSP} refers to Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kWconnected \times SVG \times ISR \times WHFd \times CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting
= 1.25[392]

CF = Summer Peak Coincidence Factor for measure
= See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)

For example a 400W connected load being controlled in an office:

$$\Delta kW = 0.4 * 0.3 * 0.98 * 1.25 * 0.60$$

$$= 0.09 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) \times 0.70 \times 0.003413 \times 0.23 / 0.75$$
$$= -\Delta kWh \times 0.00065$$

Where:

0.7 = Aspect ratio[393]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating[394]

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[392] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[393] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

0.75 = Assumed heating system efficiency[395]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $55.[396]

Measure Life

The measure life is assumed to be 10 years.[397]

Operation and Maintenance Impacts

n/a

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[394] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[395] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[396] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[397] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Heating Ventilation and Air Conditioning (HVAC) End Use

High Efficiency Unitary AC - Existing

Unique Measure Code(s): CI_HV_TOS_UNIA/C_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure documents savings associated with the installation of new split or packaged unitary air conditioning systems meeting defined efficiency criteria.

Definition of Baseline Condition

The baseline condition is a split or packaged unitary air conditioning system meeting minimum efficiency standards as presented in the 2009 International Energy Conservation Code (IECC 2009) (see table "Baseline and Efficient Efficiency Levels by Unit Capacity" below)[398].

Definition of Efficient Condition

The efficient condition is a split or packaged unitary air conditioning system meeting minimum Consortium for Energy Efficiency (CEE) Tier 1 efficiency standards as defined below (see table "Baseline and Efficient Efficiency Levels by Unit Capacity" below).

Baseline and Efficient Efficiency Levels by Unit Capacity

Equipment Type	Size Category	Subcategory	Baseline Condition (IECC 2009)	Efficiency Condition (CEE Tier I)
Air Conditioners, Air Cooled	<65,000 Btu/h	Split system	13.0 SEER	14.0 SEER 12.0 EER
		Single package	13.0 SEER	14.0 SEER 11.6 EER
	≥65,000 Btu/h and <135,000 Btu/h	Split system and single package	11.0 EER 11.2 IEER	11.5 EER TBD IEER
	≥135,000 Btu/h and <240,000 Btu/h	Split system and single package	10.8 EER 11.0 IEER	11.5 EER TBD IEER

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[398] Integrated Energy Efficiency Ratio (IEER) requirements have been incorporated from ASHRAE 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings". IECC 2009 does not present IEER requirements.

Equipment Type	Size Category	Subcategory	Baseline Condition (IECC 2009)	Efficiency Condition (CEE Tier I)
	≥240,000 Btu/h and <760,000 Btu/h	Split system and single package	9.8 EER 9.9 IEER	10.5 EER TBD IEER
	≥760,000 Btu/h	Split system and single package	9.5 EER 9.6 IEER	9.7 EER TBD IEER

Notes: 1) All table baseline efficiency ratings assume a non-electric resistance heating section type. If electric resistance heating section (or no heating section), subtract 0.2 from each baseline efficiency rating value. 2) To date, the Consortium for Energy Efficiency (CEE) has not published efficiency requirements in terms of the Integrated Energy Efficiency Ratio (IEER). When a new specification is released, this table should be updated.

Annual Energy Savings Algorithm

For units with capacities less than 65,000 Btu/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

$$\Delta kWh = (Btu/hour/1000) \times [(1/SEERBASE - 1/SEEREE)] \times HOURS$$

For units with capacities greater than or equal to 65,000 Btu/h, the energy savings are calculated using the Energy Efficiency Ratio (EER) as follows:

$$\Delta kWh = (Btu/hour/1000) \times [(1/EERBASE - 1/EEREE)] \times HOURS$$

Where:
Btu/hour = Size of equipment in Btu/hour
= Actual Installed
SEEREE = SEER Efficiency of efficient unit
= Actual Installed
SEERBASE = SEER Efficiency of baseline unit
= Based on IECC 2009 for the installed capacity. See table above.
EEREE = EER Efficiency of efficient unit
= Actual Installed
EERBASE = EER Efficiency of baseline unit
= Based on IECC 2009 for the installed capacity. See table above.
HOURS = Full load cooling hours
= If actual full load cooling hours are unknown, assume 848 (default) [399]*.*
Otherwise, use site specific full load cooling hours information.

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[399] BG&E Development of Commercial Load Profiler for Central Air Conditioners and Heat Pumps, Version 2. 3/2/10; 848 full load cooling hours.

For example, a 5 ton unit with SEER rating of 14.0:

$\Delta kWh = (60{,}000/1000) * (1/13 - 1/14) * 848$

$= 279.6$ kWh

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = (Btu/hour/1000) \times [(1/EERBASE - 1/EEREE)] \times CF$

Where:

EERbase = EER Efficiency of baseline unit
= Based on IECC 2009 for the installed capacity. See table above.
EERee = EER Efficiency of efficient unit
= Actual installed
CF_{PJM} =PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.808 [400]
CF_{SSP} = Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)
= 0.923 [401]

For example, a 5 ton unit with EER rating of 12:[402]

$\Delta kW = (60{,}000/1000) * (1/10.8 - 1/12) * 0.808$

$= 0.45$ kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[400] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York. Combined with full load hour assumptions used for efficiency measures to account for diversity of equipment usage within the peak period hours.

[401] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

[402] Assumes baseline unit with 13 SEER converted to EER using the following estimate: EER = SEER/1.2

The incremental cost for this measure is assumed to be $100 per ton for units with capacities less than 65,000 Btu/h and $120 per ton for units with capacities greater than or equal to 65,000 Btu/h.[403]

Measure Life

The measure life is assumed to be 15 years.[404]

Operation and Maintenance Impacts

n/a

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[403] Based on personal communication with VT equipment distributors and a review of Cost Values and Summary Documentation for 2008 Database for Energy-Efficient Resources, California Public Utilities Commission.

[404] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Variable Frequency Drive (VFD)

Unique Measure Code(s): CI_MO_TOS_VFDRIVE_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure defines savings associated with installing a Variable Frequency Drive on a motor of 10 HP or less for the following HVAC applications: supply fans, return fans, exhaust fans, chilled water pumps, and boiler feedwater pumps. The fan or pump speed will be controlled to maintain the desired system pressure. The application must have a load that varies and proper controls (Two -way valves, VAV boxes) must be installed.

Definition of Baseline Condition

The baseline condition is a motor, 10HP or less, without a VFD control.

Definition of Efficient Condition

The efficient condition is a motor, 10HP or less, with a VFD control.

Annual Energy Savings Algorithm

$$\Delta kWh = [(HP \times 0.746) / \eta BASE] \times HOURS \times ESF$$

Where:

HP	*= Motor Horse Power* *= Actual controlled motor horse power*
0.746	*= kWh per HP conversion factor*
ηBASE	*= Efficiency of baseline motor* *= Actual efficiency*
HOURS	*= Annual hours of operation* *= If actual operating hours are unknown, see table "VFD Operating Hours by Application and Building Type" below. Otherwise, use site specific operating hours information.*
ESF	*= Energy Savings Factor (see table "Energy and Demand Savings Factors" below)*

For example, a 10HP motor with VFD used on supply fan application in an office (assume 90% motor efficiency and constant volume baseline control):

$$\Delta kWh = [(10 * 0.746) / 0.9] * 3,748 * 0.717$$

$$= 22,280 \text{ kWh}$$

VFD Operating Hours by Application and Building Type[405]

Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
Auto Related	4,056	1,878	6,000
Bakery	2,854	1,445	6,000
Banks, Financial Centers	3,748	1,767	6,000
Church	1,955	1,121	6,000
College - Cafeteria	6,376	2,713	6,000
College - Classes/Administrative	2,586	1,348	6,000
College - Dormitory	3,066	1,521	6,000
Commercial Condos	4,055	1,877	6,000
Convenience Stores	6,376	2,713	6,000
Convention Center	1,954	1,121	6,000
Court House	3,748	1,767	6,000
Dining: Bar Lounge/Leisure	4,182	1,923	6,000
Dining: Cafeteria / Fast Food	6,456	2,742	6,000
Dining: Family	4,182	1,923	6,000
Entertainment	1,952	1,120	6,000
Exercise Center	5,836	2,518	6,000
Fast Food Restaurants	6,376	2,713	6,000
Fire Station (Unmanned)	1,953	1,121	6,000
Food Stores	4,055	1,877	6,000
Gymnasium	2,586	1,348	6,000
Hospitals	7,674	3,180	6,000
Hospitals / Health Care	7,666	3,177	6,000
Industrial - 1 Shift	2,857	1,446	6,000
Industrial - 2 Shift	4,730	2,120	6,000
Industrial - 3 Shift	6,631	2,805	6,000
Laundromats	4,056	1,878	6,000
Library	3,748	1,767	6,000
Light Manufacturers	2,857	1,446	6,000
Lodging (Hotels/Motels)	3,064	1,521	6,000
Mall Concourse	4,833	2,157	6,000
Manufacturing Facility	2,857	1,446	6,000
Medical Offices	3,748	1,767	6,000
Motion Picture Theatre	1,954	1,121	6,000

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[405] UI and CL&P Program Savings Documentation for 2009 Program Year, October 2008.

Multi-Family (Common Areas)	7,665	3,177	6,000
Museum	3,748	1,767	6,000
Nursing Homes	5,840	2,520	6,000
Office (General Office Types)	3,748	1,767	6,000
Office/Retail	3,748	1,767	6,000
Parking Garages & Lots	4,368	1,990	6,000
Penitentiary	5,477	2,389	6,000
Performing Arts Theatre	2,586	1,348	6,000
Police / Fire Stations (24 Hr)	7,665	3,177	6,000
Post Office	3,748	1,767	6,000
Pump Stations	1,949	1,119	6,000
Refrigerated Warehouse	2,602	1,354	6,000
Religious Building	1,955	1,121	6,000
Residential (Except Nursing Homes)	3,066	1,521	6,000
Restaurants	4,182	1,923	6,000
Retail	4,057	1,878	6,000
School / University	2,187	1,205	6,000
Schools (Jr./Sr. High)	2,187	1,205	6,000
Schools (Preschool/Elementary)	2,187	1,205	6,000
Schools (Technical/Vocational)	2,187	1,205	6,000
Small Services	3,750	1,768	6,000
Sports Arena	1,954	1,121	6,000
Town Hall	3,748	1,767	6,000
Transportation	6,456	2,742	6,000
Warehouse (Not Refrigerated)	2,602	1,354	6,000
Waste Water Treatment Plant	6,631	2,805	6,000
Workshop	3,750	1,768	6,000

Energy and Demand Savings Factors[406]

HVAC Fan VFD Savings Factors		
Baseline	**ESF**	**DSF**
Constant Volume	0.717	0.466
AF/BI	0.475	0.349
AF/BI IGV	0.304	0.174
FC	0.240	0.182
FC IGV	0.123	0.039

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[406] UI and CL&P Program Saving Documentation for 2009 Program Year; energy and demand savings constants were derived using a temperature BIN spreadsheet and typical heating, cooling and fan load profiles.

HVAC Pump VFD Savings Factors		
System	**ESF**	**DSF**
Chilled Water Pump	0.580	0.401
Hot Water Pump	0.646	0.000

AF/BI = Air foil / backward incline
AF/BI IGV = AF/BI Inlet guide vanes
FC = Forward curved
FC IGV = FC Inlet guide vanes

Summary Coincident Peak kW Savings Algorithm

$$\Delta kW = [(HP \times 0.746) / \eta BASE] \times DSF \times CF$$

Where:

DSF = Demand Savings Factor (see table "Energy and Demand Savings Factors" above)
CF = Summer Peak Coincidence Factor for measure
= 0.55 (pumps) and 0.28 (fans) [407]

For example, a 10HP motor with VFD used on supply fan application in an office (assume 90% motor efficiency and constant volume baseline control):

$$\Delta kW = [(10 /* 0.746)/ 0.9] * 0.466 * 0.28$$

$$= 1.08 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure varies by controlled motor hp. See table "VFD Incremental Costs" below.

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[407] UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives - Pumps.

VFD Incremental Costs[408]

HP	Fan	Pump
5	$920	$1,710
7.5	$1,310	$2,100
10	$1,320	$2,150

Measure Life

The measure life is assumed to be 15 years for HVAC applications.[409]

Operation and Maintenance Impacts

n/a

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[408] UI and CL&P Program Savings Documentation for 2009 Program Year, October 2008.

[409] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

Electric Chillers

Unique Measure Code: CI_HV_TOS_ELCHIL_V2.0711, CI_HV_RTR_ELCHIL_V2.0711,
Effective Date: July 2011
End Date:

Measure Description

This measure relates to the installation of a new high-efficiency electric water chilling package in place of a standard efficiency electric water chilling package. This measure could relate to either a lost-opportunity or retrofit installation.

Definition of Baseline Condition

Lost-Opportunity: The baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2009 (IECC 2009), Table 503.2.3(7).

Retrofit: The baseline condition is an existing water chilling package.

Definition of Efficient Condition

The efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2009 (IECC 2009), Table 503.2.3(7).

Annual Energy Savings Algorithm

$$\Delta kWh = TONS * (IPLVbase - IPLVee) * HOURS$$

Where:

TONS	*= Total installed capacity of the water chilling package[tons]* *= Actual Installed*
IPLVbase	*= Integrated Part Load Value (IPLV)*[410] *of the baseline equipment [kW/ton]* *= For lost-opportunity: Varies by equipment type and capacity. See "Lost-Opportunity Baseline Equipment*

---

[410] Integrated Part Load Value (IPLV) is an HVAC industry standard single-number metric for reporting part-load performance.

Efficiency" table in the "Reference Tables" section below[411]
= For retrofit: the actual IPLV of the existing equipment

IPLVee = Integrated Part Load Value (IPLV) of the efficient equipment [kW/ton]
= Actual Installed

HOURS = Full load cooling hours
= If actual full load cooling hours are unknown, assume values presented in table "Default Electric Chiller Full Load Cooling Hours" in the "Reference Tables" section below. Otherwise, use site specific full load cooling hours information.

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \text{TONS} \times (\text{Full\_Loadbase} - \text{Full\_Loadee}) \times \text{CF}$$

Where:

Full_Loadbase = Full load efficiency of the baseline equipment [kW/ton]
= For lost-opportunity: Varies by equipment type and capacity. See "Lost-Opportunity Baseline Equipment Efficiency" table in the "Reference Tables" section below[412]
= For retrofit: the actual full load efficiency of the existing equipment

Full_Loadee = Full load efficiency of the efficient equipment
= Actual Installed [kW/ton]

CF_{PJM} *= PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= 0.808[413]

CF_{SSP} *= Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)*
= 0.923[414]

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[411] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

[412] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

[413] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York. Combined with full load hour assumptions used for efficiency measures to account for diversity of equipment usage within the peak period hours.

[414] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be custom.

Measure Life

The measure life is assumed to be 23 years[415].

Operation and Maintenance Impacts

n/a

Reference Tables

Lost-Opportunity Baseline Equipment Efficiency[416]

Equipment Type	Size Category	Units	Path A[a]		Path B[a]	
			Full Load	IPLV	Full Load	IPLV
Air-Cooled Chillers	<150 tons	EER	≥9.562	≥12.500	NA	NA
	≥150 tons	EER	≥9.562	≥12.750	NA	NA
Water Cooled, Electrically Operated, Positive Displacement	<75 tons	kW/ton	≤0.780	≤0.630	≤0.800	≤0.600
	≥75 tons and <150 tons	kW/ton	≤0.775	≤0.615	≤0.790	≤0.586
	≥150 tons and <300 tons	kW/ton	≤0.680	≤0.580	≤0.718	≤0.540
	≥300 tons	kW/ton	≤0.620	≤0.540	≤0.639	≤0.490
Water Cooled, Electrically Operated, Centrifugal	<150 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥150 tons and <300 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥300 tons and <600 tons	kW/ton	≤0.576	≤0.549	≤0.600	≤0.400
	≥600 tons	kW/ton	≤0.570	≤0.539	≤0.590	≤0.400

a. Compliance with IECC 2009 can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or B.

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[415] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, "http://www.ctsavesenergy.org/files/Measure Life Report 2007.pdf"

[416] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

Default Electric Chiller Full Load Cooling Hours[417]

Building Type	System Type[a]	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Community College	CAV w/ economizer	752	781	836	777	897	833	952
Community College	CAV w/o economizer	1,010	1,048	1,121	1,044	1,202	1,117	1,274
Community College	VAV w/ economizer	585	607	649	605	695	647	736
High School	CAV w/ economizer	428	440	463	439	489	462	511
High School	CAV w/o economizer	819	830	851	829	875	850	896
High School	VAV w/ economizer	306	316	336	315	359	335	379
Hospital	CAV w/ economizer	1,307	1,341	1,406	1,338	1,479	1,403	1,543
Hospital	CAV w/o economizer	2,094	2,135	2,213	2,130	2,302	2,210	2,379
Hospital	VAV w/ economizer	1,142	1,165	1,208	1,162	1,257	1,206	1,300
Hotel	CAV w/ economizer	2,972	2,972	2,971	2,972	2,971	2,971	2,971
Hotel	CAV w/o economizer	3,166	3,165	3,163	3,165	3,161	3,163	3,159
Hotel	VAV w/ economizer	2,953	2,958	2,967	2,957	2,977	2,966	2,986
Large Retail	CAV w/ economizer	987	1,011	1,057	1,009	1,109	1,055	1,155
Large Retail	CAV w/o economizer	1,719	1,730	1,750	1,729	1,772	1,749	1,792
Large Retail	VAV w/ economizer	817	838	877	835	921	875	959
Office Building	CAV w/ economizer	700	710	729	709	750	728	768

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[417] HOURS estimates developed from data presented in "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", TecMarket Works, October 15, 2010, adjusted to Mid-Atlantic region using cooling degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

Building Type	**System Type**[a]	**Dover, DE**	**Wilmington, DE**	**Baltimore, MD**	**Hagerstown, MD**	**Patuxent River, MD**	**Salisbury, MD**	**Washington D.C.**
Office Building	CAV w/o economizer	2,162	2,193	2,252	2,189	2,318	2,249	2,377
Office Building	VAV w/ economizer	670	685	716	684	749	714	779
University	CAV w/ economizer	796	822	871	819	925	868	974
University	CAV w/o economizer	1,103	1,135	1,198	1,132	1,267	1,194	1,329
University	VAV w/ economizer	626	645	682	643	724	680	760

a. "CAV" refers to constant air volume systems whereas "VAV" refers to variable air volume systems.

Gas Boiler

Unique Measure Code: CI_HV_TOS_GASBLR_V2.0711, CI_HV_RTR_GASBLR_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure relates to the installation of a high efficiency gas boiler in the place of a standard efficiency gas boiler. This measure could be either a lost-opportunity or retrofit installation.

Definition of Baseline Condition

Lost-Opportunity: The baseline condition is a gas boiler equal to the requirements presented in the International Energy Conservation Code 2009 (IECC 2009). See the "Lost-Opportunity Baseline Equipment Efficiency" table in the "Reference Tables" section

Retrofit: The baseline condition is an existing gas boiler

Definition of Efficient Condition

The efficient condition is a high-efficiency gas boiler exceeding the requirements presented in the International Energy Conservation Code 2009 (IECC 2009). See the "Lost-Opportunity Baseline Equipment Efficiency" table in the "Reference Tables" section.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = CAP \times HOURS \times (1/EFF_{base} - 1/EFF_{ee}) / 1,000,000$$

Where:

CAP = *Equipment capacity [Btu/h]*
= *Actual Installed*

HOURS = *Full Load Heating Hours*
= *See "Heating Full Load Hours" table in the "Reference Tables" section below*[418]

EFF_{base} = *The efficiency of the baseline equipment; Can be expressed as thermal efficiency (E_t), combustion efficiency (E_c), or Annual Fuel Utilization Efficiency (AFUE), depending on equipment type and capacity.*
= *For lost-opportunity: See "Lost-Opportunity Baseline Equipment Efficiency" table in the "Reference Tables" section below*[419]
= *For retrofit: the actual efficiency of the existing equipment*

EFF_{ee} = *The efficiency of the efficient equipment; Can be expressed as thermal efficiency (E_t), combustion efficiency (E_c), or Annual Fuel Utilization Efficiency (AFUE), depending on equipment type and capacity.*
= *Actual Installed*

1,000,000 = *Btu/MMBtu unit conversion factor*

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be \$0.012 per Btu/h for units <300,000 Btu/h and \$0.10 per Btu/h for units >= 300,000 Btu/h[420].

Measure Life

The measure life is assumed to be 20 years[421].

Operation and Maintenance Impacts

n/a

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[418] HOURS estimates developed from data presented in "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", TecMarket Works, October 15, 2010, adjusted to Mid-Atlantic region using heating degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

[419] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(5) Boilers, Gas- and Oil-Fired, Minimum Efficiency Requirements.

[420] Incremental Cost based on analysis of proprietary vendor data from models such as MicoFlame, DynaFlame, NY Thermal, Patterson Kelley and more, and from DOE "Energy Conservation Program for Certain Industrial Equipment: Test Procedures and Energy Conservation Standards for Commercial Heating, Air-Conditioning, and Water Heating Equipment Final Rule Technical Support Document". September 14, 2009.

[421] Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

Reference Tables

Lost-Opportunity Baseline Equipment Efficiency[422]

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency
Boilers, Gas-fired	<300,000 Btu/h	Hot water	80% AFUE
		Steam	75% AFUE
	>=300,000 Btu/h and <=2,500,000 Btu/h	Minimum capacity	75% E_t and 80% E_c
	>2,500,000 Btu/h	Hot water	80% E_c
		Steam	80% E_c

Heating Full Load Hours[423]

Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	676	692	620	657	451	507	559
Auto Repair	2,292	2,344	2,106	2,229	1,543	1,728	1,901
Big Box Retail	286	298	241	271	107	151	192
Fast Food Restaurant	957	983	866	926	590	681	766
Full Service Restaurant	988	1,016	891	956	597	694	784
Grocery	286	298	241	271	107	151	192
Light Industrial	867	885	803	845	608	672	732
Motel	659	667	632	650	547	575	601
Primary School	978	993	926	960	767	819	868
Religious Worship	750	754	737	746	698	711	723
Small Office	511	524	466	496	329	374	416
Small Retail	657	674	595	636	410	471	528
Warehouse	556	576	487	533	278	347	411
Other	805	823	739	783	541	606	667

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[422] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(5) Boilers, Gas- and Oil-Fired, Minimum Efficiency Requirements.

[423] HOURS estimates developed from data presented in "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", TecMarket Works, October 15, 2010, adjusted to Mid-Atlantic region using heating degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

Gas Furnace

Unique Measure Code: CI_HV_TOS_GASFUR_V2.0711, CI_HV_RTR_GASFUR_V2.0711
Effective Date:
End Date:

Measure Description

This measure relates to the installation of a high efficiency gas furnace with capacity less than 225,000 Btu/h with an electronically commutated fan motor (ECM) in the place of a standard efficiency gas furnace. This measure could be either a lost-opportunity or retrofit installation.

Definition of Baseline Condition

Lost-Opportunity: The baseline condition is a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 80% with a standard efficiency furnace fan.

Retrofit: The baseline condition is an existing gas furnace.

Definition of Efficient Condition

The efficient condition is a high-efficiency gas furnace with an AFUE of 90% or higher. This characterization only applies to furnaces with capacities less than 225,000 Btu/h with an electronically commutated fan motor (ECM).

Annual Energy Savings Algorithm[424]

$\Delta kWh = 733\ kWh$[425]

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0.19\ kW$[426]

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[424] Energy and Demand Savings come from the ECM furnace fan motor. These motors are also available as a separate retrofit on an existing furnace.

[425] Deemed savings from ECM Furnace Impact Assessment Report. Prepared by PA Consulting for the Wisconsin Public Service Commission 2009. Based on in depth engineering analysis and interviews taking into account the latest research on behavioral aspects of furnace fan use.

[426] Efficiency Vermont Technical Reference User Manual No. 2010-67a. Measure Number I-A-6-a.

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = CAP \times HOURS \times [(1/AFUE_{base}) - (1/AFUE_{ee})] / 1{,}000{,}000$$

Where:

CAP = *Capacity of the high-efficiency equipment [Btu/h]*
= *Actual Installed*
HOURS = *Full Load Heating Hours*
= *See "Heating Full Load Hours" table in the "Reference Tables" section below*[427]
$AFUE_{base}$ = *Annual Fuel Utilization Efficiency of the baseline equipment*
= *For lost-opportunity: 0.80*[428]
= *For retrofit: the actual AFUE of the existing equipment*
$AFUE_{ee}$ = *Annual Fuel Utilization Efficiency of the efficient equipment*
= *Actual Installed.*
1,000,000 = *Btu/MMBtu unit conversion factor*

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $0.009 per Btu/h[429].

Measure Life

The measure life is assumed to be 18 years[430].

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[427] HOURS estimates developed from data presented in "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", TecMarket Works, October 15, 2010, adjusted to Mid-Atlantic region using heating degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

[428] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(4) Warm Air Furnaces and Combination Warm Air Furnaces/Air-Conditioning Units, Warm Air Duct Furnaces and Unit Heaters, Minimum Efficiency Requirements. Review of GAMA shipment data indicates a more suitable market baseline is 80% AFUE. The baseline unit is non-condensing.

[429] Incremental Cost based on analysis of proprietary vendor data from models from Gibson and Frigadaire, and from DOE "Energy Conservation Program for Certain Industrial Equipment: Test Procedures and Energy Conservation Standards for Commercial Heating, Air-Conditioning, and Water Heating Equipment Final Rule Technical Support Document". September 14, 2009.

Operation and Maintenance Impacts

n/a

Reference Tables

Heading Full Load Hours[431]

Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	676	692	620	657	451	507	559
Auto Repair	2,292	2,344	2,106	2,229	1,543	1,728	1,901
Big Box Retail	286	298	241	271	107	151	192
Fast Food Restaurant	957	983	866	926	590	681	766
Full Service Restaurant	988	1,016	891	956	597	694	784
Grocery	286	298	241	271	107	151	192
Light Industrial	867	885	803	845	608	672	732
Motel	659	667	632	650	547	575	601
Primary School	978	993	926	960	767	819	868
Religious Worship	750	754	737	746	698	711	723
Small Office	511	524	466	496	329	374	416
Small Retail	657	674	595	636	410	471	528
Warehouse	556	576	487	533	278	347	411
Other	805	823	739	783	541	606	667

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[430] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, "http://www.ctsavesenergy.org/files/Measure Life Report 2007.pdf"

[431] HOURS estimates developed from data presented in "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", TecMarket Works, October 15, 2010, adjusted to Mid-Atlantic region using heating degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory

Dual Enthalpy Economizer

Unique Measure Code: CI_HV_RTR_DEECON_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure involves the installation of a dual enthalpy economizer to provide free cooling during the appropriate ambient conditions. This measure applies only to retrofits.

Definition of Baseline Condition

The baseline condition is the existing HVAC system, without dual enthalpy economizer controls.

Definition of Efficient Condition

The efficient condition is the HVAC system with dual enthalpy economizer controls.

Annual Energy Savings Algorithm

$$\Delta kWh = TONS * SF$$

Where:

TONS = Actual Installed
SF = Savings factor for the installation of dual enthalpy economizer control [kWh/ton],
= See "Savings Factors" table in "Reference Tables" section below[432]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0\ kW^{433}$$

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[432] kWh/ton savings from "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", TecMarket Works, October 15, 2010, scaled based on enthalpy data from New York City and Mid-Atlantic cities from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $400 for a dry bulb economizer baseline and $800 for a fixed damper baseline[434].

Measure Life

The measure life is assumed to be 10 years[435].

Operation and Maintenance Impacts

n/a

Reference Tables

Savings Factors[436]

Savings Factors (kWh/ton)	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown , MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	26	22	25	29	25	27	25
Big Box Retail	144	125	143	165	141	155	139
Fast Food	37	32	37	42	36	40	36
Full Service Restaurant	29	25	29	34	29	32	28
Light Industrial	24	21	23	27	23	25	23
Primary School	40	34	39	45	39	43	39
Small Office	177	153	175	201	173	189	171
Small Retail	90	78	89	103	88	97	87
Religious	6	5	6	6	6	6	6
Warehouse	2	2	2	2	2	2	2
Other	58	50	57	66	57	62	56

---

[433] Demand savings are assumed to be zero because economizer will typically not be operating during the peak period.

[434] Cost ranges from $250-$400 when going from a dry bulb economizer baseline; only one source gives cost of going from a fixed damper baseline ($800)

[435] General agreement among sources; Recommended value from Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

[436] kWh/ton savings from NY Standard Approach Model, with scaling factors based on enthalpy data from NYC and Mid-Atlantic cities.

Refrigeration End Use

Efficient Freezer

Unique Measure Code(s): CI_RF_TOS_FREEZER_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency packaged commercial reach-in freezer, typically used by foodservice establishments.

Definition of Baseline Condition

The baseline condition is a standard-efficiency packaged commercial reach-in freezer.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified, high-efficiency packaged commercial reach-in freezer.

Annual Energy Savings Algorithm

$$\Delta kWh = (kWhBASEdailymax - kWhEEdailymax) \times 365$$

Where:

$kWhBASEdailymax$[437] $= 0.40V+1.38$ (solid door)
$= 0.75V+4.10$ (glass door)

$kWhEEdailymax$[438]

Solid Door Cabinets:

$0<V<15$: $<=0.250V+1.250$
$15<=V<30$: $<=0.400V-1.000$
$30<=V<50$: $<=0.163V+6.125$

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[437] Nadel, S. Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, 12/2002.

[438] High Efficiency Specifications for Commercial Refrigerators and Freezers, Consortium for Energy Efficiency, 1/1/2010.

50<=V: <=0.158V+6.333

Glass Door Cabinets:

0<V<15: <=0.607V+0.893
15<=V<30: <=0.733V-1.000
30<=V<50: <=0.250+13.5000
50<=V: <=0.450V+3.500

Chest Configuration:
Solid or Glass Door Cabinets:
<=0.270V+0.130

V = Association of Home Appliances Manufacturers (AHAM) volume

For example, for a 50 ft^2 solid door refrigeration unit:

ΔkWh = ((0.4*50+1.38)-(0.158*50+6.333))*365

= 2608.7 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = (ΔkWh/HOURS) x CF

Where:

HOURS = Full load hours
= 5858 [439]
CF = Summer Peak Coincidence Factor for measure
= 0.772 [440]

For example, for a 50 ft^2 solid door refrigeration unit:

ΔkW = (2608.7 / 5858) * 0.772

= 0.34 kW

---

[439] Efficiency Vermont Estimate, Derived from Washington Electric Coop data by West Hill Energy Consultants.

[440] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York. Combined with full load hour assumptions used for efficiency measures to account for diversity of equipment usage within the peak period hours.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost [441]

The incremental cost for this measure is assumed to be:

0<V<=32:	$150
32<V<=60:	$200
60<=V<80:	$250.

Measure Life

The measure life is assumed to be 9 years.[442]

Operation and Maintenance Impacts

n/a

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[441] Nadel, S. Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, 12/2002.

[442] Energy Savings Potential for Commercial Refrigeration Equipment, Arthur D. Little, Inc., 1996.

Hot Water End Use

C&I Heat Pump Water Heater

Unique Measure Code(s): CI_WT_TOS_HPCIHW_V1.0510
Effective Date: May 2010
End Date:

Measure Description

This measure relates to the installation of a Heat Pump water heater in place of a standard electric water heater. This measure could relate to either a retrofit or a new installation.

Definition of Baseline Condition

The baseline condition is a standard electric water heater.

Definition of Efficient Condition

The efficient condition is a heat pump water heater.

Annual Energy Savings Algorithm

$$\Delta kWH = (kBtu\_req / 3.413) \times ((1/EFbase) - (1/EFee))$$

Where:

kBtu_req (Office) = Required annual heating output of office (kBtu)
= 6,059 [443]
kBtu_req (School) = Required annual heating output of school (kBtu)
= 22,191 [444]

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[443] Assumes an office with 25 employees; According to 2003 ASHRAE Handbook: HVAC Applications, Office typically uses 1.0 gal/person per day.
Assumes an 80F temperature rise based on a typical hot water holding tank temperature setpoint of 140F and 60F supply water. Actual supply water temperature will vary by season and source.
Water heating requirement equation adopted from FEMP Federal Technology Alert: Commercial Heat Pump Water Heater, 2000.

[444] Assumes an elementary school with 300 students; According to 2003 ASHRAE Handbook: HVAC Applications, Elementary School typically uses 0.6 gal/person per day of operation. Assumes 37 weeks of operation.
Assumes an 80F temperature rise based on a typical hot water holding tank temperature setpoint of 140F and 60F supply water. Actual supply water temperature will vary by season and source.
Water heating requirement equation adopted from FEMP Federal Technology Alert: Commercial Heat Pump Water Heater, 2000.

3.413 = *Conversion factor from kBtu to kWh*
EFee = *Energy Factor of Heat Pump domestic water heater*
= *2.0*[445]
EFbase = *Energy Factor of baseline domestic water heater*
= *0.904*[446]
ΔkWH Office = (6,059 / 3.413) * ((1/0.904) - (1/2.0))
= 1076.2 kWh
ΔkWH School = (22,191 / 3.413) * ((1/0.904) - (1/2.0))
= 3941.4 kWh

If the deemed "kBtu_req" estimates are not applicable, the following equation can be used to estimate annual water heating energy requirements:

kBtu_req = *GPD x 8.33 x 1.0 x WaterTempRise x 365*

Where:
GDP = *Average daily hot water requirements (gallons/day)*
= *Actual usage (Note: days when the building is unoccupied must be included in the averaging calculation)*
8.33 = *Density of water (lb/gallon)*
1.0 = *Specific heat of water (Btu/lb-°F)*
WaterTempRise = *Difference between average temperature of water delivered to site and water heater setpoint (°F)*
365 = *Days per year*

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh / Hours * CF

Where:
Hours (Office) = *Run hours in office*
= *5885*[447]
Hours (School) = *Run hours in school*
= *2218*[448]

---

[445] Efficiencies based on ENERGY STAR Residential Water Heaters, Final Criteria Analysis: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterDraftCriteriaAnalysis.pdf
[446] Ibid.
[447] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.
[448] Ibid.

CF (Office) measure = *Summer Peak Coincidence Factor for office*
= *0.630* [449]

CF (School) measure = *Summer Peak Coincidence Factor for school*
= *0.580* [450]

ΔkW Office = (1076.2 / 5885) * 0.630
= 0.12 kW

ΔkW School = (3941.4 / 3.413) * 0.580
= 1.03 kW

If annual operating hours and CF estimates are unknown, use deemed HOURS and CF estimates above. Otherwise, use site specific values.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $925.[451]

Measure Life

The measure life is assumed to be 10 years.[452]

Operation and Maintenance Impacts

n/a

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[449] Ibid.

[450] Ibid.

[451] Cost based on ENERGY STAR Residential Water Heaters, Final Criteria Analysis: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterDraftCriteriaAnalysis.pdf

[452] Vermont Energy Investment Corporation "Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status" November 2005.

Plug Load End Use

"Smart-Strip" plug outlets

Unique Measure Code: CI_PL_TOS_SMARTS_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure relates to the installation of a "smart-strip" plug outlet in place of a standard "power strip," a device used to expand a single wall outlet into multiple outlets. This measure is assumed to be a lost-opportunity installation.

Definition of Baseline Condition

The baseline condition is a standard "power strip". This strip is simply a "plug multiplier" that allows the user to plug in multiple devices using a single wall outlet. Additionally, the baseline unit has no ability to control power flow to the connected devices.

Definition of Efficient Condition

The efficient condition is a "smart-strip" plug outlet that functions as both a "plug multiplier" and also as a plug load controller. The efficient unit has the ability to essentially disconnect controlled devices from wall power when the "smart strip" detects that a controlling device, or master load, has been switched off. The efficient device effectively eliminates standby power consumption (phantom power) for all controlled devices[453] when the master load is not in use.

Annual Energy Savings Algorithm

$\Delta kWh = 24\ kWh$[454]

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0\ kW$[455]

Annual Fossil Fuel Savings Algorithm

n/a

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[453] Most "smart-strips" have one or more uncontrolled plugs that can be used for devices where a constant power connection is desired such as fax machines and wireless routers.

[454] Deemed savings from "State of Ohio Energy Efficiency Technical Reference Manual", Vermont Energy Investment Corporation, August 2010.

[455] Deemed savings from "State of Ohio Energy Efficiency Technical Reference Manual", Vermont Energy Investment Corporation, August 2010.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $16 for a 5-plug $26 for a 7-plug[456].

Measure Life

The measure life is assumed to be 4 years[457].

Operation and Maintenance Impacts

n/a

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[456] NYSERDA Measure Characterization for Advanced Power Strips

[457] David Rogers, Power Smart Engineering, "Smart Strip Electrical Savings and Usability," October 2008

APPENDIX

A. Supporting Calculation Work Sheets

For each of the embedded excel work sheets below, double click to open the file and review the calculations.

1. Clothes Washer Calculation Sheet
2. MidAtlantic CFL adjustments.xls - this contains 6 tabs; the first details the ISR and Measure Life adjustments, the second the CFL delta watts multiplier calculations, and the remaining tabs show the Operation and Maintenance calculations for RES CFL, RES Interior Fixture, RES Exterior Fixtures and C&I CFL.

B. Recommendation for Process and Schedule for Maintenance and Update of TRM Contents

C. Description of Unique Measure Codes

Clothes Washer Work Sheet - ENERGY STAR and CEE TIER 3

1. Calculate kWh savings per year per machine:

kWh Savings per machine = Washer Volume* (1/BaseMEF - 1/EFFMEF) * # Cycles

ENERGY STAR 2010	217.2
ENERGY STAR 2011	267.9
CEE TIER 3	309.3

Where:		Source:
Washer Volume	3.23	Average of in VT program
Base MEF	1.26	Federal Standard
ESTAR 2010 MEF	1.8	Energy Star minimum standard
ESTAR 2010 MEF	2	New Energy Star minimum standard
CEE TIER 3 MEF	2.2	CEE Tier 3 Standard
# Cycles	282	Weighted average of 2005 Residential Energy Consumption Survey (RECS) for Mid Atlantic. http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc11.10.pdf

2. Divide savings by end use for washer and dryer operation:

Electricity Consumption by End Use for Washer/Dryer Operation	Electricity Consumption Percent by End Use	ENERGY STAR 2010			ENERGY STAR 2011			CEE TIER 3		
		Electric	Gas	Oil	Electric	Gas	Oil	Electric	Gas	Oil
Water Heating	26%	56.5	0.24	0.24	69.6	0.30	0.30	80.4	0.34	0.34
CW Machine Operation	7%	15.2	n/a	n/a	18.8	n/a	n/a	21.7	n/a	n/a
Dryer	67%	145.5	0.50	n/a	179.5	0.61	n/a	207.3	0.71	n/a
Total	**100%**	217.2			267.9			309.3		

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3. Calculate Water Pump Savings

	Water	
Baseline 2010	16.2	Calculated based on ENERGY STAR calculator
Baseline 2011	9.5	New Federal Standard WF
ENERGY STAR 2010	7.5	Energy Star minimum standard
ENERGY STAR 2011	6	New Energy Star minimum standard
CEE Tier 3	4.5	CEE Tier 3 Standard

	ENERGY STAR 2010	ENERGY STAR 2011	CEE TIER 3		
Annual Water Savings/load	28.1	11.3	16.2	Gal	Calculated based on ENERGY STAR calculator
Annual Gallons saved	7940	3193	4561	Gal	Calculated
Annual CCF	10.6	4.3	6.1	CCF	Calculated
Water Pump Savings	31.0	12.5	17.8	kWh	0.0039kWh Community/Municipal Water and Wastewat

4. Multiply savings by DHW and Dryer Fuel Mix

Residential Lighting Markdown Impact Evaluation (2009)

p59

Table 5–21: Calculation of First-Year and Lifetime Installation Rates

Measure	Markdown	Measure Life	Both
Total number of products	1,202	168	1,370
Number of products ever installed[a]	921	129	1,050
First-year installation rate	**76.60%**	**76.80%**	**76.60%**
Number of products likely to be installed in future[b]	250	37	287
Lifetime number of products to be installed[c]	1,171	166	1,337
Lifetime installation rate	**97.40%**	**99.10%**	**97.60%**

Initial Install Rate (From Empower Study)	0.81
Lifetime Install Rate (from 2009 RLW study)	0.97
Therefore 'future install'	0.16

initial product life (based on Jump et al report)	5.2 yrs

Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs
Table 6-7: Reasons for Not Installing Products Purchased through the RLP (p67)

% of future installs to replace CFLs (bought as spares)	57%
% of future installs to replace incandescents	43%

To reflect additional future savings from units replacing CFLs in future

Measure Life	5.7 yrs

To account for additional installs replacing incandescents - assume installed in first year.

Install Rate	0.88

B. Recommendation for Process and Schedule for Maintenance and Update of TRM Contents

Once developed, the Mid-Atlantic TRM will benefit from an objective and thoughtful update process. Defining a process that coordinates with the needs of users, evaluators, and regulators is critical. Below we outline our preliminary proposal for a process for the update of information and recommendations on the coordination of the timing of this process with other critical activities.

Proposed TRM Update Process

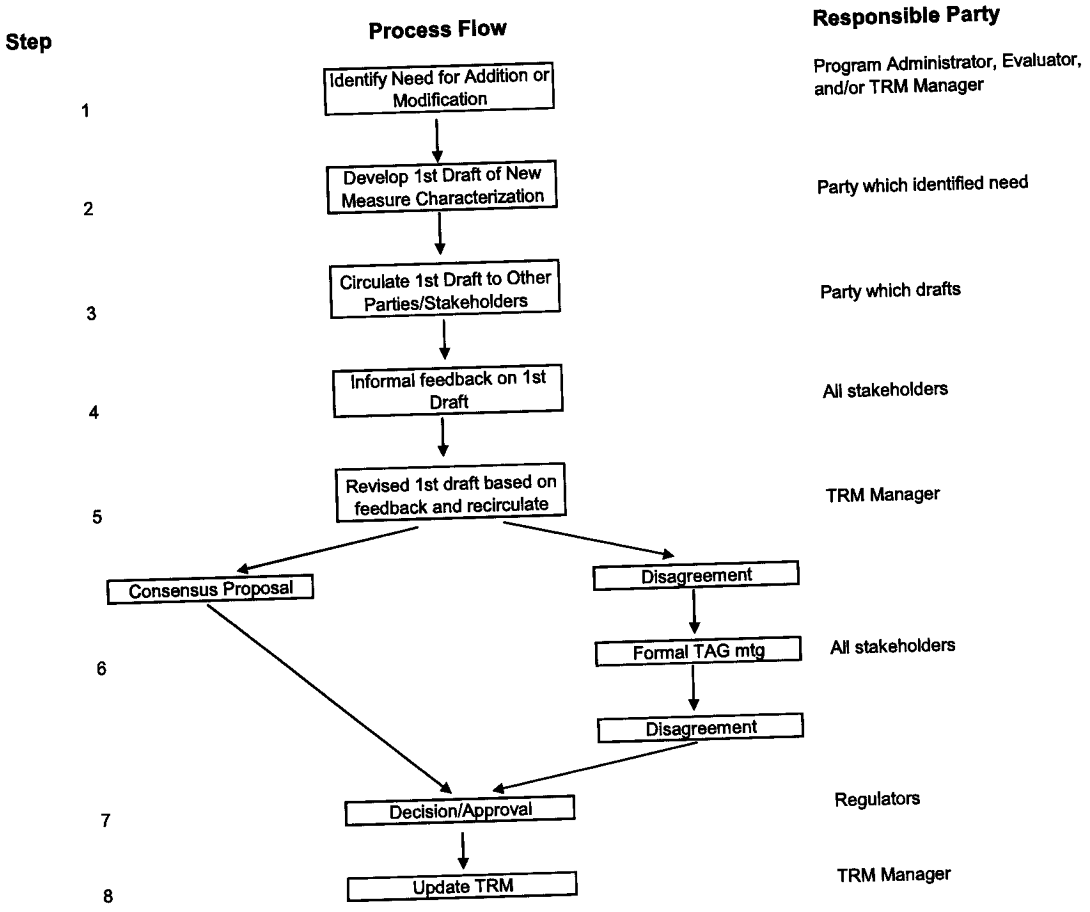
Once a TRM has been developed, it is vital that it is kept up to date, amended, and maintained in a timely and effective manner. There are three main points in time when a TRM is most likely to require changes:

1. New measure additions - As new technologies become cost effective, they will need to be characterized and added to the manual.
2. Existing measure updates - Updates will be required for a number of reasons. Examples include: the federal standard for efficiency of a measure is increased; the qualification criteria are altered; the measure cost falls; or a new evaluation provides a better value of an assumption for a variable. In such cases, the changes must be flagged and appropriate changes made to the TRM.
3. Retiring existing measures - When the economics of a measure become such that it is no longer cost effective, or the free rider rate is so high that it is not worth supporting, the measure should be retired.

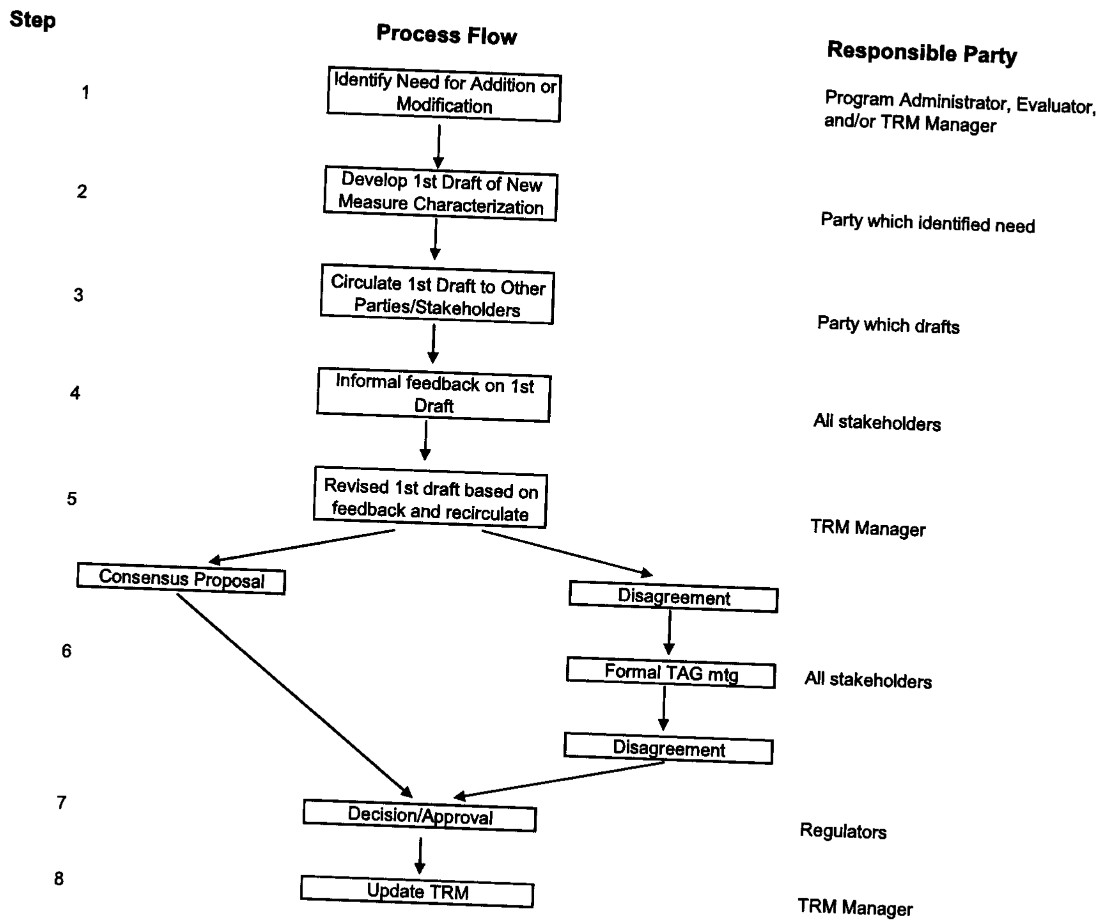
It is important to maintain a record of changes made to the TRMs over time. It is therefore recommended to establish and maintain a Master Manual, containing all versions of each TRM in chronological order, and an abridged User Manual, in which only the current versions of active measures are included. Archived older information can be made available on a website or other accessible location.

The flowchart presented below outlines steps that will result in effective review and quality control for TRM updates.

TRM Update Process Flow Chart



TRM Update Process Flow Chart



Key Roles and Responsibilities

This process requires a number of different roles to ensure effectiveness, sufficient review, and independence. The specific parties who will hold these roles in the Mid-Atlantic TRM maintenance context will need to be identified by jurisdiction. The following list of key responsibilities is given as a starting place:

- Program administrators (utilities, MEA, SEU)
    - Identifies need for new or revised measure characterization (usually due to program changes or program/market feedback)
    - Researches and develops 1st draft measure characterizations when it identifies need
    - Develops 2nd draft measure characterizations following feedback on 1st draft from all parties
    - Feedback on draft measure characterizations from other parties

    - Participant in Technical Advisory Group (TAG) for formal discussion and dispute resolution when needed
    - Input to regulators if TAG process does not resolve all issues
- Independent TRM Manager (consultant or mutually agreed upon nominee)
    - Identifies need for revised measure characterization (usually based on knowledge of local or other relevant evaluation studies)
    - Researches and develops 1st draft measure characterizations when it identifies need
    - Feedback on 1st draft measure characterizations from other parties
    - Develops 2nd draft measure characterizations following feedback on 1st draft from all parties
    - Leads Technical Advisory Group (TAG) for formal discussion and dispute resolution when needed
    - Input to regulators if TAG process does not resolve all issues
    - Manages and updates TRM manuals
- Evaluators
    - Identifies need for revised measure characterization (usually based on local evaluation studies it has conducted or managed)
    - Input on draft measure characterizations developed by other parties
    - Participates in TAG meetings when appropriate
    - Performs program evaluation - includes statewide market assessment and baseline studies, savings impact studies (to measure the change in energy and / or demand use attributed to energy efficiency), and other energy efficiency program evaluation activities
    - Verifies annual energy and capacity savings claims of each program and portfolio
- Regulators/Commission staff
    - May serve as ultimate decision maker in any unresolved disputes between implementers, evaluators, and TRM Manager

Note that the process and responsibilities outlined above assume that the manager of the TRM is an entity independent from the program administrators. This is the approach the state of Ohio has recently adopted, with the Public Utilities Commission hiring a contractor to serve that function. Alternatively, the TRM could be managed by the Program Administrators themselves. That approach can also work very well as long as there is an independent party responsible for (1) reviewing and (2) either agreeing with proposed additions/changes or challenging such changes - with the regulators having final say regarding any disputes.

The process outlined above also assumes that there are several potential stages of "give and take" on draft modifications to the TRM. At a minimum, there is at least one round of informal feedback and comment between the program administrators and the independent reviewer (TRM manager or otherwise). Other parties could be invited to participate in this process as well. In the event that such informal discussions do not resolve all issues, the participants may find it beneficial to establish a Technical Advisory Group (TAG) to provide a more formal venue for resolution of technical disputes prior to any submission to the regulators. This group would include representation from the program administrators, the evaluators (when deemed useful), the TRM Manager, and Commission staff. The mission of such a group would be to discuss and reach agreement on any unresolved issues stemming from new measure proposals, savings verifications, or evaluations. They could also review and comment on the methodology and associated assumptions underlying measure savings calculations and provide an additional channel for transparency of information about the TRM and the savings assessment process.

Coordination with Other Savings Assessment Activities

Although the TRM will be a critically important tool for both DSM planning and estimation of actual savings, it will not, by itself, ensure that reported savings are the same as actual savings. There are two principal reasons for this:

1. **The TRM itself does not ensure appropriate estimation of savings.** One of the responsibilities of the Independent Program Evaluators will be to assess that the TRM has been used appropriately in the calculation of savings.
2. **The TRM may have assumptions or protocols that new information suggests are outdated.** New information that could inform the reasonableness of TRM assumptions or protocols can surface at any time, but they are particularly common as local evaluations or annual savings verification processes are completed. Obviously, the TRM should be updated to reflect such new information. However, it is highly likely that some such adjustments will be made too late to affect the annual savings estimate of a program administrator for the previous year. Thus, there may be a difference between savings estimates in annual compliance reports and the "actual savings" that may be considered acceptable from a regulatory perspective. However, such updates should be captured in as timely a fashion as possible.

These two issues highlight the fact that the TRM needs to be integrated into a broader process that has two other key components: an annual savings verification process and on-going evaluation.

In our view, an annual savings verification process should have several key features.

1. It should include a review of data tracking systems used to record information on efficiency measures that have been installed. Among other things, this review should assess whether data appear to have been appropriately and accurately entered into the system.

2. It should include a review of all deemed savings assumptions underlying the program administrators' savings claims to ensure that they are consistent with the TRM.
3. It should include a detailed review of a statistically valid, random sample of custom commercial and industrial projects to ensure that custom savings protocols were appropriately applied. At a minimum, engineering reviews should be conducted; ideally, custom project reviews should involve some on-site assessments as well.
4. These reviews should be conducted by an independent organization with appropriate expertise.
5. The participants will need to have a process in place for quickly resolving any disputes between the utilities or program administrators on the one hand and the independent reviewer on the other.
6. The results of the independent review and the resolution of any disagreements should ideally be very transparent to stakeholders.

Such verification ensures that information is being tracked accurately and in a manner consistent with the TRM. However, as important as it is, verification does not ensure that reported savings are "actual savings". TRMs are never and can never be perfect. Even when the verification process documents that assumptions have been appropriately applied, it can also highlight questions that warrant future analysis that may lead to changes to the TRM. Put another way, evaluation studies are and always will be necessary to identify changes that need to be made to the TRM. Therefore, in addition to annual savings verification processes, evaluations will periodically be made to assess or update the underlying assumption values for critical components of important measure characterizations.

In summary, there should be a strong, sometimes cyclical relationship between the TRM development and update process, annual compliance reports, savings verification processes, and evaluations. As such, we recommend coordinating these activities. An example of the timeline established from such a coordinated process is given below.

In this example, it assumed that updates to the TRM occur only in the second half of the year. One option is to establish two specific update deadlines: one at the end of August and the other at the end of December. The first would ensure that the best available data are available for utility planning for the following year. The second would ensure that best available assumptions are in place prior to the start of the new program year. The rationale for not updating the TRM during the first half of the year is that time is usually devoted, in part, to documenting, verifying and approving savings claims from the previous year. For example, the program administrator will likely require two months to produce its annual savings claim for the previous year. An independent reviewer will then require two to three months to review and probe that claim, with considerable back and forth between the two parties being very common. Typically, final savings estimates for the previous year are not finalized and approved until June.

Needless to say, the definitive schedule for savings verification and TRM updating will need to be developed with considerable input from state regulators. This plan and timeline will be also informed by each region's Independent Program Evaluator and the EM&V plans they propose.

Annual Verification and TRM Update Timeline (example)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Utility	Draft annual savings report		No TRM submittal during SV				Draft new or updated TRMs developed and submitted to TRM Manager, participate in TAG					
				[illegible]			Technical Advisory Group (TAG) negotiations and evaluation					
Evaluator			Savings Verification (SV)									
			No TRM review during SV				Refers need for TRM updates to TRM Manager, provides input on TRMs					
TRM Manager/ Implementation staff					[illegible]		Draft new or updated TRMs developed, Review drafts provided by utilities, participate in TAG, propose new or updated TRMs					

C. Description of Unique Measure Codes

Each measure included in the TRM has been assigned a unique identification code. The code consists of a string of five descriptive categories connected by underscores, in the following format:
Sector_End Use_Program Type_Measure_TRMversionv#.MonthYear

A description of the abbreviations used in the codes is provided in the tables below:

SECTOR	
RS	Residential
CI	Commercial & Industrial
END USE	
LT	Lighting
RF	Refrigeration
HV	Heating, Ventilation, Air Conditioning
WT	Hot Water
LA	Laundry
SL	Shell (Building)
MO	Motors and Drives
PROGRAM TYPE	
TOS	Time of Sale
RTR	Retrofit
ERT	Early Retirement
INS	Direct Install
MEASURE	
CFLSCR	Compact Fluorescent Screw-In
CFLFIN	Compact Fluorescent Fixture, Interior
CFLFEX	Compact Fluorescent Fixture, Exterior
REFRIG	Refrigerator
FANMTR	Furnace Fan Motor
RA/CES	Window Air Conditioner Energy Star
RA/CT1	Window Air Conditioner Tier 1
CENA/C	Central Air Conditioner
SHWRHD	Low Flow Showerhead
FAUCET	Low Flow Faucet
HWWRAP	Water Tank Wrap
HPRSHW	Heat Pump Water Heater, Residential
CWASHES	Clothes Washer, Energy Star
CWASHT3	Clothes Washer, Tier 3
WINDOW	Window, Energy Star
HPT8	High Performance T8 Lighting
T5	T5 Lighting

MHFIN	Metal Halide Fixture, Interior
MHFEX	Metal Halide Fixture, Exterior
SODIUM	High Pressure Sodium Lighting
LECEXI	LED Exit Sign
DELAMP	Delamping
OSWALL	Occupancy Sensor, Wall box
UNIA/C	Unitary Air Conditioning system
EMOTOR	Efficient Motor
VFDRIVE	Variable Frequency Drive
FREEZER	Freezer
HPCIHW	Heat Pump Water Heater, Commercial

Northeast Energy Efficiency Partnerships

MODEL PROGRESSIVE BUILDING ENERGY CODES POLICY FOR NORTHEAST STATES

A White Paper of the NEEP Building Energy Codes Policy Project

March 2009

TABLE OF CONTENTS

Model Progressive Building Energy Codes Policy for Northeast States

Acknowledgements

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1. Executive Summary

Northeast Energy Efficiency Partnerships' (NEEP) Model Progressive Building Energy Code Policy delineates comprehensive measures to maximize the energy savings potential of the building energy codes that govern new building construction and major additions in the Northeast states.[1] The ultimate goal of these guidelines is to support state adoption and implementation of policies that will lead the majority of new building construction by 2030 to be comprised of "net-zero energy" buildings.[2]

NEEP developed this white paper in response to expressed public policy needs for guidance in creating and/or adopting building energy policies that will result, ultimately, in large-scale energy and carbon emissions savings in the built environment across the region. If building energy codes in Northeast states were to require all new buildings constructed by 2030 to be net-zero energy buildings, the region collectively would realize 663 trillion BTUs annually in energy savings and a reduction of 35 million metric tons annually of carbon emissions. These savings correspond to (for the Northeast region) approximately 7.5 percent of current energy use of residential and commercial buildings and 12 percent of current carbon dioxide emissions emitted by electricity generating power plants.

This white paper highlights each element of the policy and includes suggested enabling statutory language, explanations of the specific policies, the manner in which the policy relates to other energy efficiency policies such as appliance standards and ratepayer-funded (or "systems benefit charge," i.e. SBC) energy efficiency programs, and references to industry and policy best practices. This paper also includes state-level estimates of the energy and carbon savings potential of progressively more stringent building energy codes that reduce building energy consumption.

NEEP's Model Progressive Building Energy Codes Policy includes three areas of concentration:

Code Adoption

The Policy addresses the need to regularly update state building energy codes to reflect the most recent editions of national model building energy codes - specifically, the International Energy Conservation Code (IECC) - and recommends that states participate actively in national model energy code update processes to advance energy efficiency. It also recommends that the state "Authority Having Jurisdiction" [3](AHJ) include as part of their building energy codes an "Informative Appendix" that constitutes "above code" or "beyond code" building standards, such as the New Buildings Institute Core Performance Guide and ENERGY STAR for Homes.® The Informative Appendix

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[1] Northeast states include: Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

[2] A net-zero energy buildings as a residential or commercial building with greatly reduced energy use through energy efficiency gains such that the balance of energy needs can be supplied with renewable technologies. There is, however, no ultimate consensus definition of net-zero energy buildings. In fact, there are many definitions of net-zero energy buildings. The above definition is taken from a paper submitted to the 2006 American Council for an Energy Efficient Economy Summer Study. *Zero-energy buildings: A critical look at the definition*. Torcellini et al. http://www.nrel.gov/docs/fy06osti/39833.pdf

[3] Authority Having Jurisdiction: The state, county or municipal government charged with adoption, administration or enforcement of a regulation or code.

provides a guide to building professionals seeking to build more energy efficient buildings, as well as to states seeking to implement policies that promote the construction of more energy efficient buildings.

Code Compliance

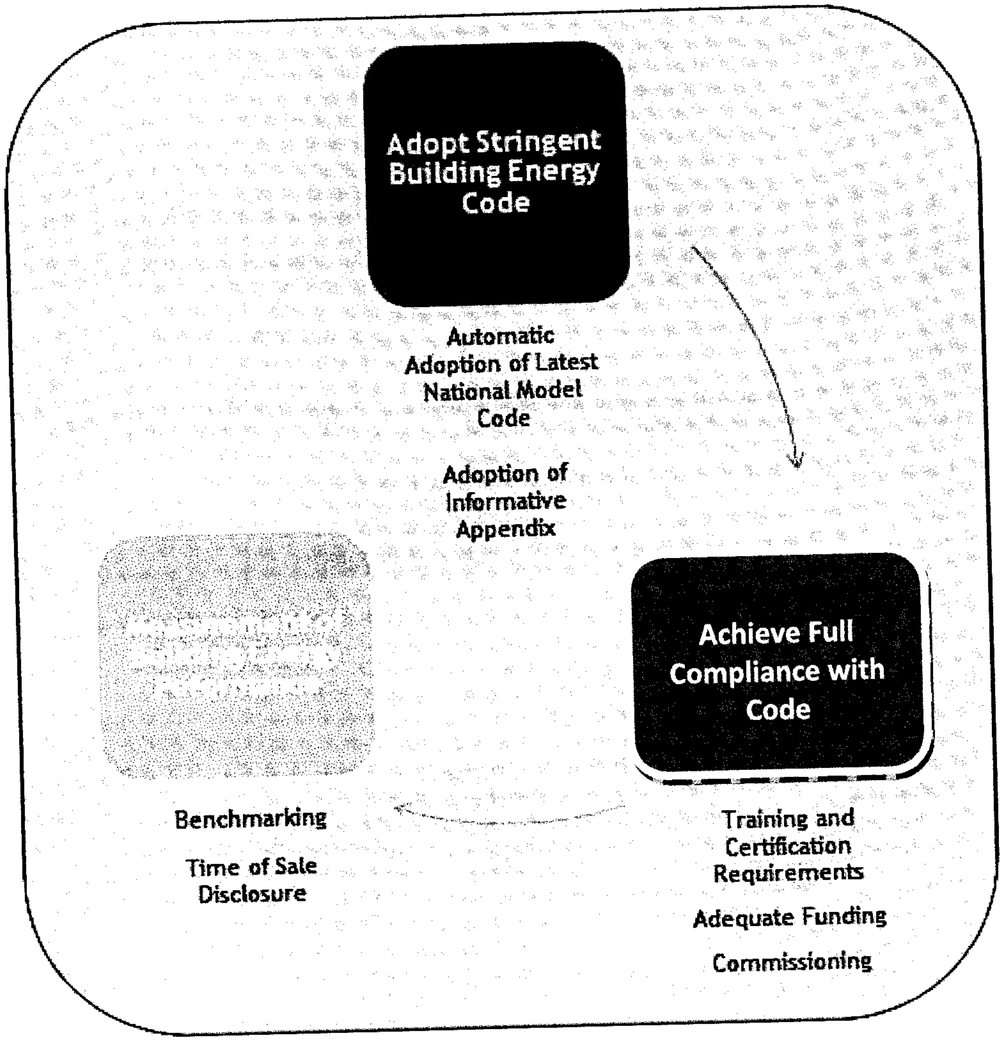
The Policy recommends methods and strategies for improving building energy code compliance such as:

- Better training and certification of code officials, building professionals and building operations and maintenance staff through the state building energy code administrator;
- Increase local and state capacities and expertise to enforce code through the use of certified independent energy code inspectors;
- Maintaining adequate funding so that code agencies can administrate, train local officials, provide technical support and finally enforce the code; and
- Tracking and reporting energy code compliance to inform progress.
- Strategic coordination with energy efficiency program administrators to train the building design community in best practices to meet and exceed minimum energy code requirements.

Measuring and Reporting Energy Performance

Lastly, the Policy highlights the need to establish requirements to measure and rate the energy performance of dwellings and commercial buildings (both new and existing). The goals of measuring building performance including establishing a market value for existing energy efficient homes and buildings, allowing policymakers to assess the impact of energy code policies to generate energy savings and ultimately improving the energy performance of both new and existing buildings. Specific measurement recommendations include the use of benchmarking and time-of sale disclosure.

Maximizing Building Energy Performance Through Codes



An effective codes policy recognizes the interdependence of policy, enforcement and measurement. Lack of compliance with the energy code undermines the potential energy savings of a code. Measurement of building performance helps determine the actual amount of energy savings in compliant (or non-compliant) buildings. Results of the measurement of building performance gives policymakers and code officials the information needed to determine the next steps in code adoption.

In summary, the authority having jurisdiction (AHJ) over building energy codes should act on the following key elements of NEEP's recommendations for the Model Progressive Building Energy Codes Policy:

Summary of Policy Recommendations

Energy Code Adoption

- The AHJ should adopt the latest edition of the national model code every three years.
- The state should participate in national model energy code update processes to advance energy efficiency.
- State amendments to the national model energy code should maintain or enhance the stringency or energy savings of the code.
- The AHJ should adopt an Informative Appendix for both residential and commercial buildings that is at least 20 percent more energy efficient than the base state code.
- The AHJ should maintain a Technical Advisory Committee to inform updates to the energy code and the Informative Appendix.

Energy Code Compliance

- The AHJ should train and certify all energy code inspectors.
- The AHJ should incorporate a third party inspection system such as the Specialized Plan Examiner/Inspection System originally instituted in Washington State and/or a system based on the Home Energy Rating System Index (HERS).
- The AHJ should institute a fee for service structure that sets aside dedicated funding for plan review and inspections of energy code.
- The AHJ should adopt commissioning requirements as part of the building energy code. The commissioning requirements should cover work prior to and after the achievement of a certificate of occupancy.
- Commissioning should include all building systems including HVAC, lighting.

Measuring Building Energy Performance

- The AHJ should require the measurement and disclosure of residential dwelling and commercial building energy performance prior to sale of existing and new buildings.
- The AHJ should require the labeling of all buildings with information on energy performance.
- The AHJ should require improvements in energy performance at the time of sale.
- The AHJ should require the energy performance benchmarking of all commercial buildings.
- For benchmarking, the state should require the use of the EPA Portfolio Manager or equivalent.

2. Introduction

A. Goals of NEEP Progressive Building Energy Codes Policy

The goal of the Policy is to dramatically improve the energy efficiency of both new and existing buildings. Ultimately, for new construction the goal is to make net-zero energy buildings the standard of construction. Buildings consume 40 percent of the energy and 70 percent of the electricity in the U.S.[4] Unlike automobiles, appliances or other energy consuming devices, buildings, by their very nature, are meant to last, meaning that a building built today will have an impact on our energy use for 50 to 100 years or more. Therefore, any effective energy policy must address building energy use. Adopting and effectively implementing energy efficient statewide building energy codes represents one of the most cost-effective ways of reducing building energy consumption in new construction and substantial building renovation, including building additions. **To realize the goal of net-zero energy buildings, states must adopt progressively stronger building energy codes. These progressively more stringent codes will lead to continual improvements in building practices such that by 2030, net-zero energy buildings should comprise the majority of new construction.** ***The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) has set goals for the increasing stringency of the 90.1 building standard with the intent of reaching net zero energy standards by 2031.***[5]

The following graph shows the building energy performance goals set for the ASHRAE 90.1 standard en route to the goal of net-zero energy buildings as approved by the ASHRAE Board of Directors. ASHRAE 90.1 is one of the two recognized national model codes.

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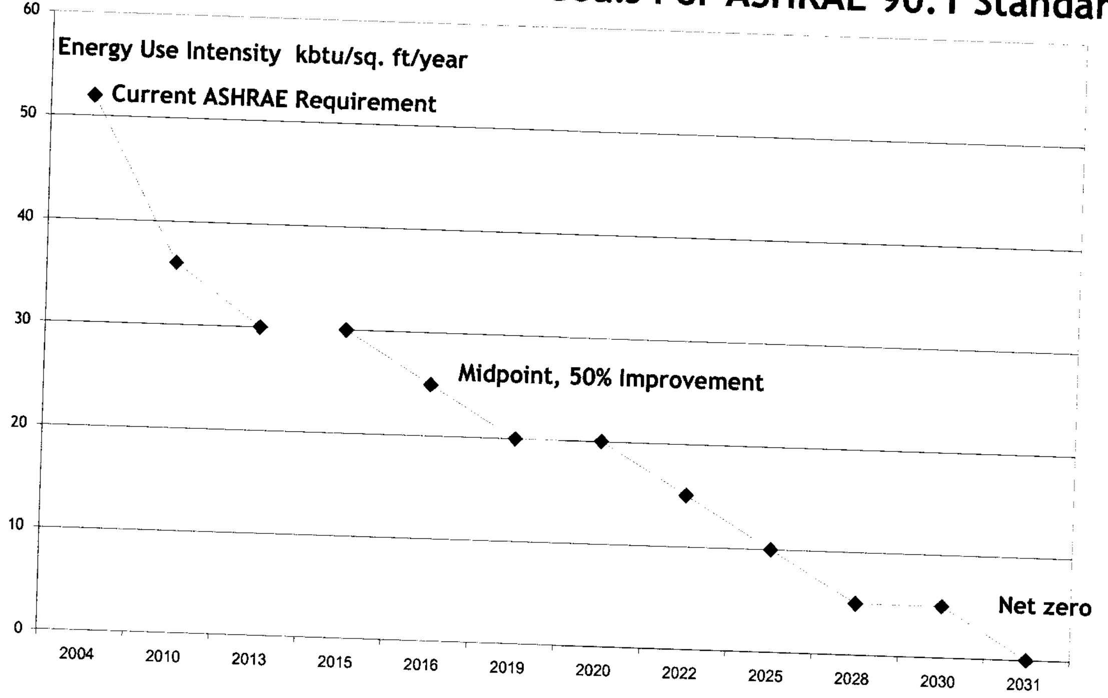
[4] United States Environmental Protection Agency; Buildings and the Environment, A Statistical Summary; December 20, 2004

[5] NEEP staff chart based on information derived from ASHRAE. Please see www.ashrae.org/



Building Energy Performance Goals For ASHRAE 90.1 Standard

B. How Building Energy Codes Reduce Energy Consumption in Buildings

Building energy codes set a floor for energy efficiency in new construction by establishing minimum energy efficiency requirements for all new and renovated homes and buildings. These efficiency requirements affect the design, materials, and equipment installed in dwellings and buildings which reduce the energy inputs needed to maintain healthy, comfortable and fully functioning indoor environments over the life of the building. Because the energy code applies to all construction, it affects energy consumption across all building types and sizes.

Improving the energy code generates energy savings in a consistent and long lasting manner. As noted above, buildings last a long time and an energy efficient building has the potential to save energy throughout that span. However improvements to state energy codes have typically been slow to occur. Progressive changes to national model energy codes require significant research to identify, test and incorporate new building methods and technologies. Moreover, some states have been reluctant to adopt those model codes with regularity, some preferring to instead use their own state-specific codes which, though often based on model codes, can take significant amounts of time to vet and adapt.

Beyond adoption, high levels of compliance with the code requires intensive education of building professionals from designers to builders, as well as code officials, on both the state and local levels. Finally, measuring building energy use requires the continual development of effective tools and methodologies to accurately gauge the energy footprint of a building. All of this takes time. Under current policies in Northeast states, building energy performance is upgraded only when renovations or replacements occur. As a result, an inefficient building built today will typically remain inefficient for decades. Therefore, states must act decisively to regularly improve energy efficiency in the building code.

Potential Energy and Environmental Savings

Adopting and implementing strong building energy codes - as well as providing informed guidance on the construction and renovation of beyond-code, high performance buildings - provides an effective means of tackling the twin goals of reducing energy use in the region and lowering emissions of greenhouse gases.

Under a progressive building energy codes policy energy savings and reduced carbon dioxide emissions for the Northeast add up rapidly. If Northeast states adopt residential building energy codes that are 30 percent above the current national model energy code by 2011 and achieve full compliance, energy savings would rise every year so that by 2019 the Northeast would realize savings of 63 trillion BTUs per year. Similar action regarding commercial energy codes would total savings of 104 trillion BTUs. If Northeast states adopt codes requiring net-zero energy buildings by 2030, by 2050 energy use in the region would drop by 594 trillion BTUs per year in residential buildings and 1.25 quadrillion BTUs (quads) annually from commercial buildings.[6]

The lower energy use of a progressive building energy code policy can have a substantial impact on carbon dioxide emissions as measured against similar benchmarks. By 2019, annual carbon dioxide emissions could drop by 8 million metric tons in the Northeast. Annual CO_2 savings could increase to 32 million metric tons by 2029 as a result of implementing building energy codes that increase energy efficiency by 70 percent over current national model codes in 2020. Finally, by 2050, building energy codes mandating net-zero energy buildings will result in carbon dioxide emission savings of almost 99 million metric tons per year. This is equivalent to removing more than 16 millions cars from the road.[7] For more details see Appendix A.

The following graph demonstrates how building energy codes can help meet regional environmental goals. If all states in the region adopt and achieve full compliance with energy efficient codes, the carbon dioxide savings (as shown in Appendix A), by 2018 will generate one-third of the required carbon dioxide emission reductions specified in the Regional Greenhouse Gas Initiative.

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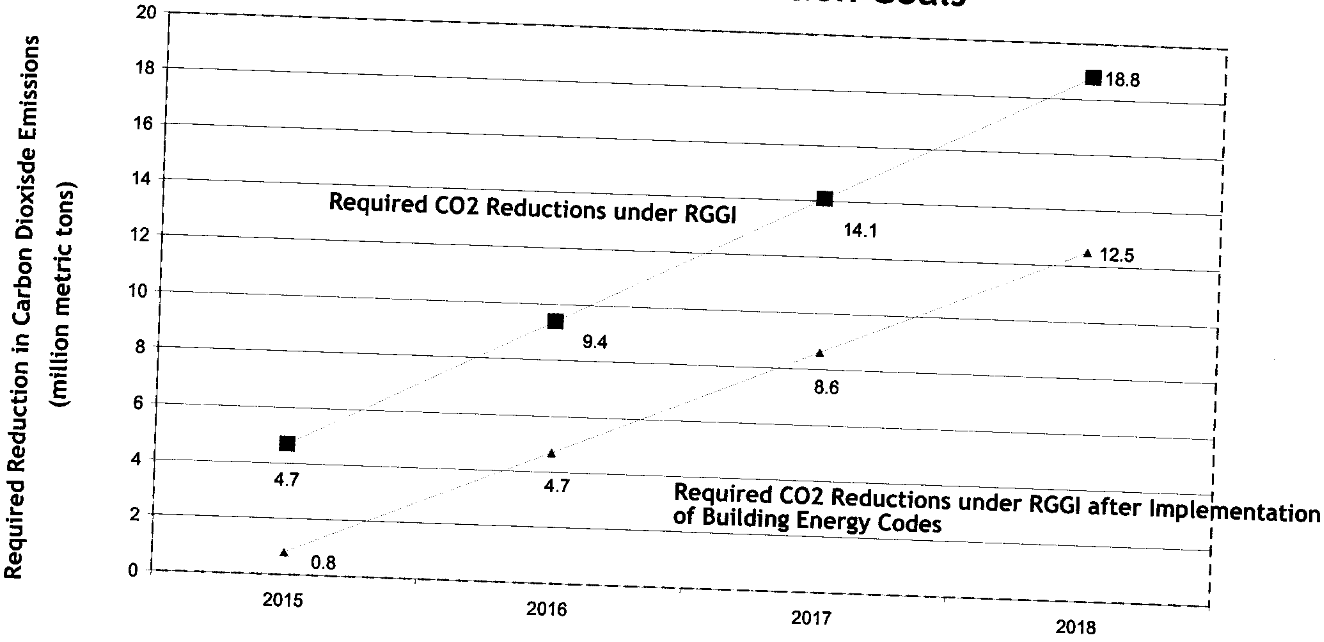
[6] The amount of energy savings accumulates rapidly because once a building gets built efficiently, it lasts for decades. Thus, a home built efficiently in 2015 will still be part of the total energy savings in 2035, for example.

[7] According to the United States Environmental Protection Agency: http://www.epa.gov/climatechange/emissions/ind_calculator.html



How Improving Building Energy Codes by 30% affect Northeast Carbon Dioxide Reduction Goals

Fully enforcing codes that go 30% above the current national model code would make a large contribution towards meeting regional Northeast carbon dioxide reduction goals developed through the Regional Greenhouse Gas Initiative (RGGI). RGGI aims to reduce carbon dioxide emissions by 10 percent between 2015 and 2018[8].

D. Need for Comprehensive Approach to Building Energy Codes

Any one of the measures discussed in this white paper would improve building energy code policy. However, to ensure the ultimate goal of reducing building energy consumption, policymakers must pursue a comprehensive approach to building energy codes, including compliance and measurement. Increased code stringency alone will not guarantee energy savings unless construction actually conforms to these heightened requirements. Compliance with the code results from a combination of building practices, such as the use of commissioning, along with properly trained building inspectors and maintenance staff. In order to know whether compliance goals are being achieved, robust methodologies designed to measure building performance must be implemented. Finally, because building energy codes address only new construction or substantial renovations, a comprehensive policy must also address the energy performance of existing buildings.

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[8] See http://www.rggi.org/docs/RGGI_Executive_Summary.pdf

E. Integrating Building Energy Codes with Other Energy Efficiency and Environmental Policies

The various public policies that currently govern energy efficiency in Northeast states, such as building codes, appliance standards and ratepayer-funded energy efficiency programs, are interconnected, and good policy design will facilitate the ability for all to work together to maximize savings potential. Appliance efficiency standards are often included as part of building energy codes in ways such as heating and cooling equipment. State code agency staff should know the statutory requirements for HVAC and lighting efficiency standards both at the federal level and in their own state. The state staff should make sure that code requirements do not diverge from minimum appliance efficiency standards to prevent confusion among building inspectors as to the actual required equipment efficiency. If states want to exceed statutory requirements for appliances, understanding these requirements can guide state code agency staff in designing the more stringent code requirements.

Energy efficiency programs exist to motivate developers and building owners to construct energy efficient buildings that exceed the state building energy code requirements and in the process help building professionals acquire the skills necessary to reduce energy consumption in building operations. This, in turn, allows for consistent improvements with respect to the ability of building professionals to adapt to updated and enhanced building energy codes.

A benefit of coordinating statutory (codes) and voluntary (efficiency programs) efforts is the increased recognition by regulators that as energy codes increase in stringency, baselines above which efficiency programs work must also rise. Program administrators and regulators should carefully analyze voluntary programs before the adoption of new codes so that program designs promotes technologies and products that are significantly more efficient than the new code. These actions maintain an appropriate distance between the efforts to "raise the ceiling" on building technologies and practices (programs) and efforts to "set a floor" on the minimum required energy savings generated by the building energy codes. These discussions and analyses must explicitly recognize that efficiency programs themselves generate zero savings from their ratepayer funding for code training and compliance under current regulatory constructs, a dynamic that itself may merit change.

Building energy code agencies and other stakeholders (building code and energy efficiency advocacy organizations; organizations of building professionals; and others) should work with energy efficiency program administrators, promoting the exchange of information to ensure that the program administrators are aware of energy code changes that may affect program designs, and inform appropriate code updates. In addition, opportunities will exist for state building code administrators to collaborate with the energy efficiency program administrators on training and certification programs, particularly because the program administrators already have established relationships with many building professionals.

Attention to the efforts at integration should extend to other energy efficiency related efforts. For example, a progressive energy code policy would be an integral part of the development of high performance building protocols and specifications for buildings such as schools or hospitals. The protocols and/or specifications would undoubtedly incorporate strong building energy codes as a minimum baseline for energy performance and mandate engagement of and participation in the related energy efficiency programs

Finally, states should endeavor to integrate building energy codes into environmental policy efforts such as climate change. Already, strengthening building energy codes comprise key parts of climate change action plans in states such as Rhode Island, Connecticut and Maine.

A building code policy properly integrated with energy efficiency programs should result in:

1. **The building energy code as a clear and consistent statewide "construction baseline"** to assess the costs and savings of residential, commercial and industrial energy efficiency programs the promote advanced efficiency in homes and buildings

2. **The "advanced code" informative appendix as the technical basis for ratepayer-funded energy efficiency** programs that promote advanced efficiency in new construction, renovation and remodeling. (See Section A2)

3. **Efficiency program administrators' active support for and participation in energy code** update processes at the state and national levels, and energy code training and technical support.

3. Policy Recommendations

A comprehensive and effective building energy code policy requires the adoption of stringent code requirements, institution of effective means of enforcing the code requirements, and on-going measurement and documentation of building energy use to guide policy development and implementation to truly result in lower energy consumption. The following sections detail the elements of a Model Progressive Building Energy Code Policy. To illustrate the integrated nature of the various elements of such a Policy, the table below shows how stakeholders interact with the different policies.

Involvement of Various Stakeholders in Progressive Building Energy Codes

	[redacted]	Code Compliance	Building Energy Measurement
Energy Efficiency Program Administrators	[redacted]	• Coordinate/Integrate Advanced Efficiency Program Training and Technical Support with Energy Code Training and Technical Support • Fund Energy Code Training and Technical Support	• Include Building Benchmarking as Program Element
Building Professionals[9]	[redacted]	• Assist Training of Local Code Officials • Develop capacities to meet and exceed minimum energy code • Identify energy code implementation issues	• Provide information needed for building energy benchmarking and to assess energy code compliance
State Code Offices	[redacted]	• Train and certify energy code inspectors (state, local, third party) • Maintain statewide energy code training for regulated community • Maintain technical support tools and services	• Maintain up to date building energy performance benchmark • Establish electronic data systems to monitor code compliance • Assess energy code

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[9] The definition of "Building Professionals" includes architects, engineers, contractors and building operators.

		Code Compliance	**Building Energy Measurement**
	[redacted]	• Oversee local code enforcement	compliance rates and issues
State Energy/ Public Utility Commissions	[redacted]	• Encourage Efficiency Program support for energy code training and technical support • Include building energy code impacts in state energy planning and evaluation	• Inform building energy benchmarking policies and coordinate with overall state energy policies • Include energy benchmarking as element of efficiency programs • Train and certify building energy raters
Energy Efficiency Advocates	[redacted]	• Encourage Efficiency Program support for energy code training and technical support • Recommend code implementation tools and training resources	• Encourage and inform Time of Sale Building Energy Rating and Performance Policies
Other State Offices **(e.g., Consumer Protection)**	[redacted]	• Track energy code compliance • Encourage consumer awareness and education	• Encourage and inform Time of Sale Building Energy Rating and Performance Policies

For each proposed policy, the white paper includes: (1) policy recommendations; (2) explanation of the policy; (3) opportunities for integration with other energy efficiency policies; (4) examples of government and industry best practices; and (5) and suggested statutory language.

A. Code Adoption

1. Regularly Update the State Building Energy Code

Policy Recommendations:

a. Adopt latest national model energy code every three years.

b. The state should participate in national model energy code update processes to advance energy efficiency.

c. Restrict state amendments to national model energy code to increase overall energy savings (e.g., to increase stringency, improve compliance, etc.)

d. Maintain a Technical Advisory Committee to inform updates to the energy code and the Informative Appendix.

Policy explanation: Regular updates to the state building energy code align a state code with the latest developments in building technologies and practices. However, the process for updating a state-specific building energy code requires a significant amount of time and effort involving research and analysis, as well as coordination with other elements of state building codes, such as the mechanical and electrical codes. This often results in an extended process that leaves the energy code out of date, unnecessarily complex and out of step with codes from nearby states (particularly important in areas where building professionals work in multiple states). In addition, state code offices or other authorities having jurisdiction are often forced to complete the updates with limited resources and staff. A better process for updating state building energy codes is to automatically reference the latest edition of the national model codes as a statutory requirement, and to pursue cooperative participation in the national code change cycles with like-minded jurisdictions to influence the efficiency requirements of the model energy code.

NEEP recommends that states seek to automatically adopt the latest version of the IECC as an integral part of a comprehensive codes adoption process, such as is the case in Massachusetts, Pennsylvania, Maine, Maryland and Vermont. The IECC is the nationally recognized model energy code, developed by the International Code Council (ICC) through a rigorous amendment adoption process that ensures all changes are subject to open public comment and debate.[10] The ICC amendment process guarantees a formal process to propose amendments for committee review and recommendation, and a final vote by code officials and other state representatives from across the U.S. Furthermore, the IECC and International Existing Building Code (IEBC) integrate and work in concert with the other ICC codes, such as existing building and mechanical codes, to ensure seamless implementation and the elimination of conflicts among the various codes. The ICC process brings out the best proposals that stand the tests of consistency, energy cost reduction, energy use reduction, and reduction of greenhouse gas emissions. In the end, automatic adoption of the IECC allows the AHJ to allocate its resources to concentrate on other important functions such as improved compliance. Consistency in state energy code policies to automatically adopt the latest version of the IECC can reduce the burden for building professionals to stay abreast of and comply with state energy code requirements...

The ICC code updates occur on a three-year schedule, with two cycles of hearings between its three-year publication intervals. This cycle benefits states by providing for regular and aggressive improvements to energy

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[10] For the same reasons, NEEP also recommends that states automatically adopt the complementary International Existing Building Code (IEBC).

efficiency while also allowing time for states to incorporate new technological advances into practice and to update energy code training and enforcement materials.

The ICC incorporates amendments based on a process that depends on the participation of state code officials. **State collaboration with regional and national efforts** to increase the IECC energy efficiency requirements can leverage resources and build momentum to positively affect each new edition of the code.

Best Practices: For regular, periodic state energy code updates, NEEP recommends that:

- **First, the AHJ be required to adopt the latest version of the national model code.** Care should be taken not to introduce vague language.[11]
- **Second, any statutory language should prohibit adoption of less stringent provisions.** This is particularly important in highlighting the differences between the IECC and the International Residential Code (IRC), which, over the last several updates, have diverged in terms of energy efficiency measures. The IRC has either adopted weaker standards or failed to adopt strong new standards included in the IECC. Therefore, states should link all prescriptive requirements to the IECC either by simply adopting the IECC or through amendments to the IRC. Alternatively, a state could simply delete the energy chapter of the IRC (Chapter 11) simultaneous with its adoption of the latest IECC. Because of the slightly different requirements, adopting both energy codes will inevitably lead to confusion.[12]
- **Third, to provide for a well informed building code adoption processes, state code offices should maintain a Technical Committee** such as those found in New York and Massachusetts to inform code updates. Technical Committees are typically made up of key stakeholders that provide guidance on technical questions related to the adoption of the code. Such guidance can include pointing out possible sources of conflict with other codes or technical standards (e.g., appliance standards) as well as address the technical feasibility or cost-effectiveness of individual requirements.

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[11] This could possibly have been the case in Vermont. See Act Number 0092 Section 8 V.S.A 21 and Section 9 V.S.A 21, 2007 Legislative Session)

[12] In Maine, for example, a new building codes statute enacted in 2008 mandates adoption of both the IRC and IECC, leaving it to the newly-created Technical Building Codes and Energy Committee to resolve any inconsistencies between the two codes. Unfortunately, this situation also opens the door to the possibility that the committee may adopt the less stringent IRC provisions. Likewise, Pennsylvania law [12] allows both the IECC and the IRC and also provides an additional alternative to complying with the IRC energy provisions. Such situations are unnecessarily complicated and may reduce energy savings if the less energy efficient code is enforced.

Code Update Policy: Best Practices Examples

State	Statute
Massachusetts	Green Communities Act, Chapter 143; Section 94; Item (m) http://www.mass.gov/legis/laws/mgl/143-94.htm
Summary: The "Green Communities Act" of 2008 contains language that will tie the state energy conservation code to the IECC, and includes "anti-backsliding" language in that it requires any changes to the IECC to increase energy efficiency. The state code update must occur after each model code update.	

Suggested statutory language: *The Authority Having Jurisdiction (AHJ) shall adopt, at least every three years, the latest edition of the International Energy Conservation Code (IECC), published by the International Code Council, together with any other more stringent energy efficiency provisions that the {AHJ} concludes are warranted. No amendments to the energy conservation code or the existing building code shall be adopted that will result in a net increase in energy consumption in buildings.*

2. Include an Informative Appendix to the State Energy Code

Policy Recommendations

a. States should adopt an Informative Appendix for both residential and commercial buildings that is at least 20 percent more energy efficient than the base state code.

Policy Explanation: In recent years, municipalities have shown increased interest in building energy codes that are more energy efficient than the national model codes or adopted state energy codes. Alternatively referred to as "stretch code," "beyond code," or "above code," these advanced building energy standards have been included as policies in several municipalities and states in the region. Unfortunately, there has been no coordination in this effort and it has resulted in spawning a plethora of above code standards with differing baselines and measurements for achieving energy improvements. Although well-intentioned, these various policies have generated significant confusion in the marketplace, particularly in regard to defining the "above code" standard. Moreover, many new state laws include requirements for certain categories of buildings to be a certain percentage more efficient than the state energy code, a vague standard that is difficult to implement. An AHJ can address this confusion and provide guidance by adopting an "Informative Appendix," or a section of the code that contains a listing of codes and building standards that have been determined by the AHJ to be acceptable as more energy efficient codes. An Informative Appendix:

- Informs architects, engineers and other building and design professionals who are looking to build energy efficient buildings with an appropriate reference.
- Establishes criteria for ratepayer funded energy efficiency new construction programs.
- Establishes criteria for state policies to incentivize high performance buildings, such as tax credits or utility demand-side management rebates.
- Points the way for changes to future energy conservation codes.

Municipalities: For municipalities that wish to adopt building energy codes more stringent than the model national code, the Informative Appendix provides a consistent set of requirements. This ensures that the municipalities actually adopt a more stringent, enforceable code. The Informative Appendix will limit the number (and inevitable confusion and difficulty to building professionals) of multiple "stretch" codes within a state. In some states, legislation may be needed to allow municipalities to adopt energy code requirements other than the state minimum code requirements.

Support for Future Code Upgrades: The use of the Informative Appendix builds market capacities to deign and construct dwellings and buildings with advanced energy efficiency features. Developing such market "know how" supports the eventual adoption of strategies that result in net-zero energy buildings. Adoption of an informative appendix makes a state building energy code dynamic and forward-looking, providing ever increasing energy savings while working in conjunction with the baseline minimum building energy code. As such, an Informative Appendix works well, for example, within the context of state exploration of net-zero energy buildings, such as the effort currently underway in Massachusetts where the Governor has established a net-zero energy building task force with the goal of:

- Pointing the way toward broad marketability of net-zero energy residential and commercial buildings in the private sector by 2020, and universal adoption of net-zero energy buildings for new construction by 2030;
- Establishes criteria for local or state programs or policies that require state or municipal-funded construction to exceed minimum energy code requirements.
- Specifying an interim standard for state-owned construction that is significantly more stringent than the current Mass LEED Plus benchmark; and
- Developing specifications for the first state-owned net-zero energy building by January 1, 2010.[13]

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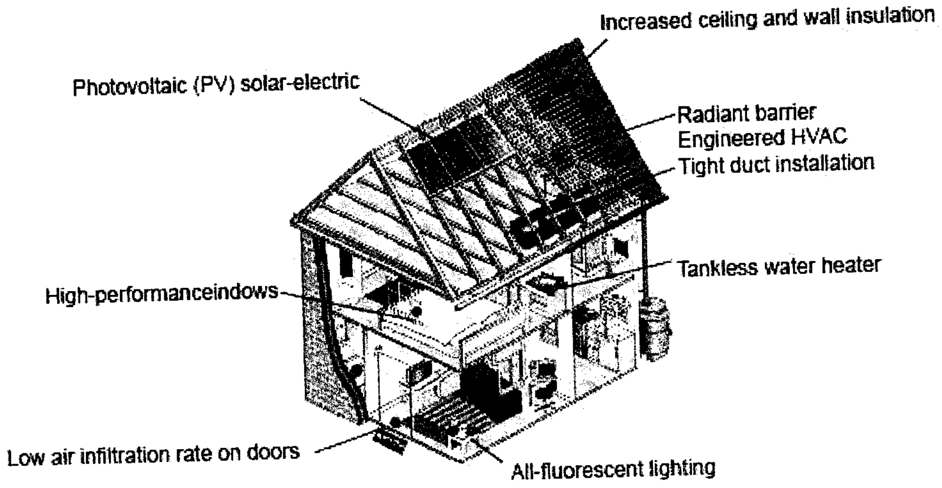
[13] More information on the Massachusetts Net Zero Energy Building Task Force can be found at www.mazneb.org.

Components of a Net-zero Home



Integration with Energy Efficiency Programs: There are two ways that the Informative Appendix can interact with energy efficiency programs. First, the Informative Appendix can be the technical basis for energy efficiency programs in new construction. Otherwise, in places where a municipality wants to adopt a stretch code, the Informative Appendix can serve as the basis for the code itself. It is important to stress, that for the second option, the utility should retain the ability to provide financial incentives to buildings meeting the Informative Appendix even though the Informative Appendix is the code.

Best Practices: Any code or standard included within an Informative Appendix must possess the following features.

- A building meeting this code or standard must exceed the energy efficiency of the current state building energy code by a given policy-directed minimum, e.g. 30 percent.
- The code or standard must be written in code-enforceable language, and not, for example, as a building energy rating model, i.e., LEED, Green Globes, etc.
- Building officials must be able to verify that the buildings meet the code or standard. (This may include programs to train building inspectors on how to inspect for compliance. The specific code or standard should include mechanisms for its enforcement such as it being tied, but not limited to, Home Energy Rating System (HERS[14]) that can provide documentation to the building official that the building meets the requirements of the code or standard being used.)
- The AHJ must specify within its adopted code that a building complying with a code or standard listed in the Informative Appendix would comply with the state energy code.

Among the advanced building guidelines that NEEP recommends for potential inclusion in an Informative Appendix are:

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[14] See Glossary for definition.

For Commercial Buildings	For single, duplex & multi-family homes

[redacted]

Suggested Statutory Language: *The AHJ shall, within one year from enactment of this section, develop specific options defining how any proposed residential or commercial building can exceed the requirements of the adopted energy conservation code by a minimum of twenty (20) percent. These options shall be set forth in such code as an Informative Appendix thereto. Any building that complies with an option listed therein shall be deemed as meeting the requirements of the energy conservation code.*

B. Energy Code Compliance

1. Develop training and certification requirements for Building Energy Code Inspectors

Policy Recommendations:

a. The AHJ should incorporate a third party inspection system such as the Specialized Plan Examiner/Inspector (SPE/I) System originally instituted in Washington State and/or a system based on the RESNET Home Energy Rating System (HERS[19]).

b. Train and certify all inspectors on building energy codes.

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[15] The Core Performance Guide is currently a standard but has been translated into code-enforceable language. See: www.neep.org for more information.

[16] It should be noted that Title 24 requirements are keyed to California specific climate zones. Prior to any other state or municipality adopting Title 24, the appropriate climate zones should be specified.

[17] The full set of proposals from the EECC is found as proposal EC-154 in the latest round of technical amendments to the IECC. The 30% improvement would not apply to jurisdictions that adopt the 2009 IECC as this code already partially incorporates the proposals in EC-154.

[18] Energy Star for Homes is roughly equivalent in stringency to the 2004 Supplement of the IECC (roughly a Home Energy Rating System score of 100). For it to function as an Informative Appendix, a jurisdiction should specify that the dwellings meet a HERS Index of no more than 70. Each point decrease in the HERS Index roughly equals a 1 percent improvement in energy efficiency.

[19] See the Glossary for definition of HERS.

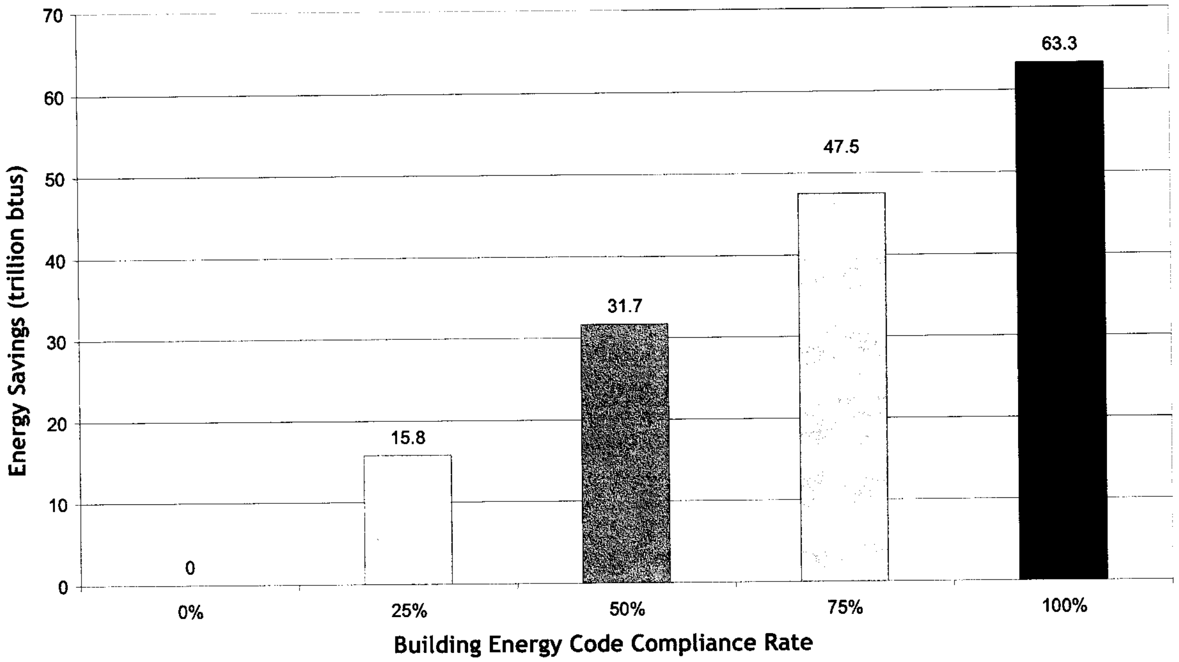
c. Establish a program to measure code compliance and building energy performance.

d. Establish a training committee to oversee the development, promotion, and delivery of training on building codes to state code officials

Policy Explanation: Having a strong energy code does not guarantee energy efficient buildings. Municipalities need adequately trained and certified inspectors to ensure that buildings comply with the energy code. Mandating energy code training, supplemented by updated procedures, would improve compliance and increase energy savings.

To understand the importance of compliance, the following chart, based on energy savings derived from analysis by the Building Codes Assistance Project, shows how simply improving the level of compliance with the building energy code markedly increases the energy savings.

Gain in Annual Energy Savings in the Northeast by 2020 Due to Increasing Compliance with Residential Building Energy Codes



Typically, energy codes compliance rates range from 40 to 60 percent, though compliance rates have gone as low as 16 percent in some jurisdictions[20].

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[20] A 2008 report by Efficiency Maine documented a compliance rate of 16 percent with the building energy code. Report on LD 1655 Building Energy Codes by the Maine Public Utilities Commission and MaineHousing.

Many states do not specifically require energy code training for code inspectors, although it is often offered as a part of their continuing education opportunities. Legislation should be crafted to specifically require the AHJ to implement or develop an energy training and certification program for inspectors to assure technical comprehension and increase code compliance. Certification of candidates who will perform commercial and residential plan review/inspections is available through the International Code Council's certification programs and testing. Or, if states so chose, they could establish and fund similar education and certification programs providing a valuable resource to their municipalities.

Integration with Programs: Program administrators could help fund and administer training and certification programs if the related regulatory constructs are modified to exclude such costs from the standard cost-effectiveness considerations and/or a methodology for attributing savings to the programs for code compliance efforts are developed.

Best Practices: The AHJ should establish a training committee to oversee the development, promotion, and delivery of training on building codes to state code officials, local inspectors, and the regulated community, such as architects, engineers and other building professionals, construction trades and facilities directors. The training committee should have the authority to approve and develop training materials and delivery options (which may include a combination of face-to-face and online training), as well as consult with building officials' education committees to ensure support and compliance. The AHJ would be charged with the responsibility for administering such programs.

The training committee should also develop an annual plan for building code training and technical support - what, where, when, who, how - that leverages resources and knowledge. One available means is through certification of commercial and residential plan review/inspections candidates conducted through the International Code Council's certification programs and testing. Training could also be accomplished through established training venues, such as community colleges and professional associations. For example, the Boston Society of Architects conducts a series of trainings throughout the state each time the Massachusetts Board of Building Regulations and Standards updates the building codes. Such training could be funded through a number of resource frameworks, including tuition, grants, and through a state's ratepayer funded energy efficiency programs.

Energy code training classes or seminars should be developed, through a regulatory process, which would cover at a minimum, the following topics:

- Energy Code and Residential Code plan review issues;
- Interpreting energy software program results;
- Integration of plan review results into inspection tasks;

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http://74.125.47.132/search?q=cache:1lerdcEqJqsJ:www.maine.gov/mpuc/staying_informed/legislative/2006legislation/BuildingEnergyCodesRpt.doc+Efficiency+Maine+Report+on+Building+Energy+Codes+2008&hl=en&ct=clnk&cd=3&gl=us

- Inspection procedures based on integration of energy issues into individual site visits;
- Field inspection issues of envelope and systems components;
- Above-code optional programs and strategies; and
- Measurement tools and criteria (such as blower door and duct blaster testing).

A well-crafted code training program should include mentoring and inspection tools development for code officials and building professionals. As part of the continuing certification of inspectors, energy conservation code modules should be a specific requirement. Also, the state should seek to increase opportunities for training of the regulated community and use state agencies and tools to market this training.

Finally, financial resources should be allocated directly to funding for energy code training, the activities of the training committee, and for the resources to fully implement training programs. Proper training and certification must have an adequate and secure source of funding; however, it does not have to be expensive.

Third Party Inspectors: The AHJ can establish a code training and certification program modeled after Washington State's SPE/I program. This program, run by a non-profit corporation formed by the state's utilities, developed and funded a training and certification program.[21] The Washington Association of Building Officials maintained a list of all qualified inspectors and made the list available to any interested party, such as builders or municipal officials, in order to provide municipalities or other interested parties a means to find the certified personnel. The program included supporting materials such as a guidebook showing how municipalities and/or builders could use the services of the inspector. Funding for such third-party inspectors could be realized from a portion of the building permit fee. States may also consider allowing existing local building inspectors to "opt in" to such a system, whereby the existing inspector could qualify as the specialized building energy code inspector, provided he/she secured the appropriate levels of training and was certified as such. In such a case, the fee for the specialized inspection would revert to the municipality. See Section 2 below for a more detailed discussion of funding options.

A second type of third party inspection could involve the use of HERS raters. A robust training and certification program already exists for the development of HERS raters. Consequently, a growing pool of qualified raters already exists. Using HERS raters fits in well with the accelerating trend of states and municipalities adopting energy codes tied to the federal ENERGY STAR program (or the use of the HERS Index directly as one way to meet code), which employs HERS raters to assure compliance. Among the strengths that energy raters bring is detailed knowledge of how to inspect for such items as duct leakage, which is an important part of the newly adopted 2009 edition of the IECC, along with generalized knowledge of the energy code and above code energy standards. Care must be taken, however, in the incorporation of energy raters (or SPE/I inspectors) into the state and local code inspection system, particularly where the possibility exists for conflicts with existing state laws when private contractors are introduced into a public function.

Establishing Baseline Studies: Finally, to ensure that code inspectors, whether municipal or third party, correctly assess code compliance in buildings, the AHJ should develop a comprehensive program designed to verify compliance of both residential dwellings and commercial buildings. Knowing the actual numbers of compliant buildings as well as the specific requirements that builders do and do not comply with will help state agencies

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[21] Although the Washington State ran on utility funding with a utility based group designing the program, the structure laid out at the beginning of the "Best Practices" section, using a state agency to design the training and certification can also work.

continually modify and improve their training programs. This work should consist of a baseline study to determine the current level of compliance, identification of specific areas where compliance is weak and recommendations on how to address these weaknesses. An example of such a study was done for the Massachusetts Board of Building Regulations and Standards in 2000.[22] Importantly, all initial baseline compliance studies should have frequent follow-up studies to gauge the effectiveness of implemented policies.

The New York State Energy Research and Development Authority (NYSERDA) plans to conduct a baseline study as part of its energy portfolio standard.[23] This study aims to identify areas of low compliance, the reasons for the low compliance and use this information in the agency's effort to train code officials. It also calls for follow up studies.

Compliance Policy: Best Practices Examples

State	Statute
Massachusetts	"Green Communities Act" Section 94 of Chapter 143; item (p) http://www.mass.gov/legis/laws/mgl/143-94.htm
Summary: This legislation requires the state's Board of Building Regulations and Standards (BBRS) to work collaboratively with the Department of Energy Resources to adopt regulations for the training and certification of energy code inspectors. It also mandates that all new construction and major renovations pass inspections by certified energy code inspectors. The statute allows for the establishment of third party inspectors.	
Maine	LD 2179 30A MRSA Section 4451 http://www.bcap-energy.org/files/ME%20LD2179.pdf
Summary: Maine's code training mandate incorporates the need for the Maine Community College System, the Department of Environmental Protection, the Department of Health and Human Services, state energy efficiency programs, and the office to all work collaboratively to establish the continuing education program. The mandate also requires that the program provide basic and advanced training in the technical and legal aspects of code enforcement necessary for certification. The legislation explicitly allows for the use of third	

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[22] *Impact Analysis of the Massachusetts 1998 Residential Code Revisions*, Prepared by XENERGY, Inc. *May 14, 2001.*

[23] See Best Practices Box Below for a link to the New York State proposal.

party inspectors.	
New York	A Strategy for Enhanced Energy Codes and Appliance Standards in New York Prepared by The New York Energy Research and Development Authority October 15, 2008 http://www.dps.state.ny.us/NYSERDA_Codes_and_Standards_Strategy_15_October_2008_FINAL.pdf
Summary: Section 4 contains a description of the plans for the training program called, *Development and Delivery of Advanced Training, Tools, Strategies, and Resources*. This section gives a detailed description of the program designed to develop training courses and find training service providers. The purpose is to provide exhaustive training to building professionals including code inspectors, architects and homebuilders. The section also gives a detailed discussion of how the agency plans to implement its baseline study.	
Washington	SPE/I Program: The Washington State Energy Code: Certification for Inspectors and Plan Reviewers for the Non-Residential Energy Code. January 1997 http://www.energycodes.gov/implement/documents/case_certify.doc
Summary: This report gives a broad overview of the third party inspection program developed and implemented by Washington State, including descriptions of successful and unsuccessful aspects of the program. It also includes important recommendations helpful to any other jurisdiction contemplating the adoption of a similar program.	

Suggested Statutory Language: *The AHJ, in consultation with [relevant state agency(s)] shall develop requirements and promulgate regulations for the training and certification of building code enforcement officials that incorporate the energy provisions of the state building code. The AHJ shall also require that all construction, reconstruction, alteration or repair*[24] *of all buildings be approved by inspectors certified in the state building code energy provisions.*

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[24] During the rulemaking process, the implementing agency will have to set (if it has not already done so) specific rules on what constitutes a major alteration or repair.

2. Provide Adequate and Stable Long Term Funding for Code Agencies

Policy Recommendations:

a. The AHJ should institute a fee for service structure that sets aside dedicated funding for plan review and inspections of energy code.

b. Permit applicants should contract directly with special energy code inspectors.

c. A stable source of funding for training and certification, technical support for the regulated community for code adoption, for code development including the Informative Appendix and for compliance reviews should be established.

Policy Explanation: Requiring inspections without supplying adequate funding for these inspections raises the issue of unfunded local mandates. Municipalities should not have to shoulder alone the financial burden of achieving better building energy code compliance. Instead, a user "fee for services" should be established and collected as a portion of building permit fees immunizing this function from budget shortfalls and allowing trained and certified energy code inspectors to supplement the work of local building inspectors. This fee could accomplish two important functions.

1. First, the fees should sufficiently fund proper review of construction drawings and inspection services of buildings during and after construction.
2. Second, a small portion of the fee could be allocated to assist the state in providing the infrastructure for code inspection training and certification, code adoption and development as well as technical support to the regulated community.

The fund generated by these fees are separate from state general funds and impose no burden on municipal governments. The fund would, nevertheless, be under the control of the municipal building department or the relevant local authority. Alternatively, responsibilities for plan check reviews and inspections should lie on special inspectors hired by the permit holder.

How Connecticut Funds its Training and Certification Infrastructure

In Connecticut, a surcharge of $0.16 per $1,000 value of permit work raises over $1 million per year for education programs. It supports training staff at the state level, outside instructors, training materials and aids, and venues where training is conducted. Such an education/certification program should embrace all code officials, building and fire, as well as other licensed and non-licensed professionals and trades on the basis of what their statutory needs are for continuing education. Those members of the building community required to attend to maintain licensure or certification are guaranteed space. These sessions can be held at local community centers. One caveat to this approach is that the fee typically applies to all aspects of building code work. Since energy code training is typically a lower priority, it is likely that only a small portion of this fee will be dedicated to energy codes.

Best Practice: Funding for plan check reviews and inspections could come directly from building permit fees. However, the jurisdiction should make sure to dedicate a certain percentage of the building fee to the energy code to make sure it is not overlooked. On the other hand, the AHJ could simply direct the developer/owner to contract directly for the energy code plan check and inspection. This approach is appealing because it makes it more likely for the energy aspects of the project to receive attention. (See SPE/I model below) Whichever funding model is used, it should also be flexible enough to allow for instances where small, rural communities need to pool resources to allow for qualified energy code inspectors to be hired on a shared basis, with compliance responsibilities based on a population formula.

Special Plan Examiner/Inspector Program

The Washington State SPE/I program provides an alternative funding strategy. Once the special inspectors were trained and certified, Washington State allowed for the permit holder (or their representative) to contract directly with the special inspector to perform the proper reviews. Section 1704 of the International Building Code provides the requisite language for enabling this function. At the end of the process, the special inspector must provide a report(s) to the building official in charge and the ultimate approval will remain with the building official.

Funding for the training and certification functions of the SPE/I program described in Section B1 was provided by the utilities in Washington. Ultimately, this funding model proved unsustainable, as once the utilities ended their funding, the program ceased to exist. Therefore, while using utility funding to start up such a program may make sense, there should a guarantee that funding will continue if (or when) utilities stop funding the program. The amount of funding needed should drop as the template for the training and certification program is established. It should be noted that the funding required for the SPE/I training and certification program was relatively minor, roughly $5 million over the three-year life of the program.

Funding for Informative Appendix

Beyond the typical work in code development, an important and non-traditional use for the building fees would be to help in the development of the Informative Appendix. Development of the Informative Appendix on a regular basis would help ensure that the state provides the necessary support to stakeholders looking to build dwellings and buildings that are more stringent than code. To the extent, that utilities or program administrators use the Informative Appendix as the basis for the new construction programs,

Inspector Funding Policy: Best Practices Examples	
Connecticut	Chapter 541 part 1A section 29-522a http://www.cga.ct.gov/2007/pub/Chap541.htm#Sec29-252a.htm
Summary: See Description Box, Page 25.	

New York	A Strategy for Enhanced Energy Codes and Appliance Standards in New York Prepared by The New York Energy Research and Development Authority October 15, 2008 http://www.dps.state.ny.us/NYSERDA_Codes_and_Standards_Strategy_15_October_2008_FINAL.pdf
Summary: This training program (described in the previous section) would be funded out of program funds that come from the energy efficiency portfolio standard. Going through a program administrator provides money but is subject to the continuation/renewal of funding.	

Suggested Statutory Language: *Local jurisdictions shall, in accordance with statute, incorporate into the building permit fee a fee structure sufficient to provide for the dedicated plan check and inspection of the energy code. The Commissioner of (XXX) shall adopt, in accordance with requirements of [statute] a schedule of fees to be added to local permit fees, adequate to defray the direct and indirect costs for administration of a training and certification program for code enforcement officials, design professionals, and building construction trades, to be known as the Codes Enforcement Training Fund. Such fee schedule shall carry forward to each subsequent fiscal year. Should the fund balance of such Fund exceed {$XXXXX} at the end of any fiscal year, such excess funds shall be deposited in the General Fund.*

3. Require Commissioning for Commercial Buildings

Policy Recommendations

a. The AHJ should adopt commissioning requirements as part of the building energy code. The commissioning requirements should cover work prior to and after the achievement of a certificate of occupancy.

b. Commissioning should include all building systems including HVAC, lighting.

Policy Explanation: Commissioning consists of a process that confirms, with extensive documentation, that building systems are planned, designed, installed, tested, operated and maintained in accordance with design requirements established at the beginning of a project.

As the technology required to construct highly efficient commercial and industrial buildings becomes more complex (particularly with the increasing use of whole building strategies), the need to ensure that all building systems (such as heating, cooling and lighting) function optimally becomes paramount. Requiring a fully integrated commissioning process from the beginning of a project assures a building owner that the building will perform as designed and will generate the designed level of energy efficiency.

The full scope of commissioning extends beyond the purview of the building codes. Many of the requirements affect not only energy, but overall performance of equipment and systems. Thus, the scope of requirements covered by the national model codes is incorporated within the mechanical code to address issues of systems design, load, sizing, control, operation and maintenance. This is a clear illustration of how energy code adoption must be comprehensive and coordinated to achieve the multiple objectives safety, health and welfare and energy efficiency. Care must be taken when trying to incorporate commissioning requirements into code for another reason. With respect to the code, the inspector's work ends upon the issuance of the Certificate of Occupancy (CO). However, proper commissioning requires the commissioning agent to review and inspect building systems after the building goes into use to ensure that all systems are, in fact, functioning properly under real load conditions. This implies that some sort of mechanism, whether a requirement or as part of a energy efficiency program, should be incorporated. Code language must provide a requirement for commissioning work to continue after the building goes into use. For example, the Washington State energy code requires that construction drawings require post construction commissioning to be provided to the building owner and provides details as to what post construction commissioning entails.

Integration with Programs: Commissioning is a part of ratepayer-funded commercial new construction programs in New York and Massachusetts. The fact that commissioning is an integral requirement of state SBC programs as well as for such programs as the Collaborative for High Performance Schools (CHPS) has meant that market actors in the field of energy efficient construction have become more familiarized and comfortable with the use of commissioning. This will facilitate the implementation of commissioning because best practices along with a growing number of practitioners already exist. Consequently, it can be an efficient use of SBC program funds if attribution of savings related to correction of deficiencies identified by program-funded mandatory commissioning is resolved. However, care must be taken to avoid having commissioning lead to relaxed implementation of SBC program requirements. It should not function as a backstop for poor construction. Instead, commissioning should function as a guiding framework, continual check and final confirmation on buildings systems.

Best Practices: Clearly, no "one size fits all" process exists for building commissioning. However, certain guidelines should be used to help maximize the benefits of commissioning. Such guidelines should adhere to some common and accepted principles in their technical application such as developing and implementing an appropriate testing program or continuously documenting all commissioning activities. See, for example, a sampling of industry best practices as developed by Portland Energy Conservation, Inc.:[25]

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[25] For a more complete description, see guidance as developed by Portland Energy Conservation Inc. at http://www.peci.org/CxTechnical/resources.html#construction

Commissioning Policy: Best Practices Examples

State	Statute
California	California Green Building Standards Code Section 504.4 http://www.document.dgs.ca.gov/bsc/prpsd_stds/2007/2007_cgbsc_9-23-08.pdf
Summary: Provides detailed instructions on how to properly conduct the Title 24 acceptance requirements.	
Washington State	Washington State Energy Code WAC-51-11-1416 http://apps.leg.wa.gov/WAC/default.aspx?cite=51-11-1416
Summary: Provides a complete set of code requirements for commissioning. Includes post-construction commissioning requirements.	

Suggested Statutory Language: The AHJ, in consultation with the [relevant state agency], shall develop requirements and promulgate regulations, requiring a process to ensure that all new non-residential buildings and any major reconstruction, alteration, or repair of all non-residential buildings perform as designed with respect to energy consumption by undergoing building commissioning. Non-residential buildings less than 50,000 square feet shall not be subject to such regulations. Initial operation and testing commissioning must be completed and approved before issuance of a permanent certificate of occupancy. Such regulations shall utilize a nationally accredited standard.

C. Measuring and Reporting Energy Baseline

1. Require the Disclosure of Home Energy Use at Time-of-Sale

Policy Recommendations:

a. States should require the measurement and labeling of residential dwelling and commercial building (both new and existing) energy performance prior to sale of the building.

b. States should require the labeling of all buildings with information on energy performance.

c. States should require improvements in energy performance at the time of sale.

Policy Explanation: Time of sale requirements address the reality that regulations governing new construction make up only one opportunity for energy savings that can be realized from residential and commercial buildings. Energy improvements to existing buildings can also generate significant savings as the number of existing buildings far outnumbers new construction. Even modest improvements spread widely among existing buildings can generate large energy savings. Unfortunately, building codes typically only address new construction or extensive renovation, as the existing building stock is grandfathered through law. Thus, mandatory time of sale energy use ratings and disclosures are a reasonable and effective way to address the energy use of existing homes and commercial buildings. Requiring energy ratings for new construction and the disclosure of energy usage of existing buildings at the time of sale creates market incentives for both builders and current owners to make energy saving improvements in both new and existing dwellings and commercial buildings. Home energy ratings can also help confirm compliance with energy code as well as help track compliance across a state or given jurisdiction.

The use of time of sale requirements can be used with respect to the sale of newly constructed homes and buildings as well. In this case, time of sale policies would help ensure that the homes and buildings up for sale actually meet code and perform as they have been designed.

Time of sale policies introduce information into the marketplace. This information, the actual energy use for a home or building, helps the market place a value on energy efficiency. This can help buyers (or sellers) finance efficiency improvements before or after properties are leased or sold (e.g., through energy efficiency mortgages for example).

Integration with Programs: Programs can help implement time-of-sale requirements if the construct is developed in such a way that savings can be attributed to the related building performance or retrofit energy efficiency programs that are typically offered in Northeast states. Time-of-sale requirements can be related to programs such as Home Performance with ENERGY STAR and commercial retrofit programs. For example, if the analysis goes beyond simple disclosure of energy bills and requires identification of cost-effective efficiency opportunities via an audit, program administrators can establish a program to help defray the cost of the audit ("test-in," in Home Performance with ENERGY STAR terms), incentivize the efficiency-related work undertaken and then fund follow-up audits ("test out," in Home Performance with ENERGY STAR terms) to ensure that any improvements actually result in energy savings.

Best Practices: Through regulatory proceedings, typically through the state department of consumer affairs (or equivalent) a state should establish guidelines for the building energy rating scoring, implementation, evaluation, labeling as well as training of inspectors for time of sale disclosure. Any effective program would cover new and existing residential dwellings and commercial buildings. In addition to the disclosure of the property's energy bills, an effective scoring guideline should include a home energy audit by a qualified energy rater and be based on an accepted home energy rating system such as HERS. Disclosure of energy conservation aspects of the property (such as envelope insulation, window u-factor, and HVAC efficiency) should be included. Historical energy use, recent energy upgrades and evaluation of proper installation should be mandated information for existing buildings. Tools such as ENERGY STAR Yardstick[26] provide even more accurate detailing of energy use without going all the way to energy audits.

While vital, the disclosure of utility information needs to be supplemented with a simple system of labeling the dwelling or building so that both sellers and buyers have a simple reference (much like miles per gallon for cars) upon which to compare buildings. The European Union currently has draft regulations in place that will require the use of "Building Energy Ratings." According to the regulations, each dwelling, whether newly constructed, sold or rented out, will include an energy performance certificate (EPC) that will indicate its energy performance (See example of certificate below). Unsurprisingly, this regulation is coupled with requirements to develop a methodology to determine energy performance (such a disclosure of energy bills, HERS or ENERGY STAR Yardstick) along with a requirement to perform an energy performance analysis[27].

To go beyond simple disclosure of energy bills and engage in home energy audits, a sufficient pool of trained and licensed certifiers or building raters within the area will be needed. A number of professionals could potentially serve in this role, but all would need proper training in order to accurately identify and relay the energy efficiency of the property to the potential buyers. In conjunction with proper training, a system should be implemented for registering the data so that all property energy efficiency disclosures are identical.

Finally, while an effective disclosure policy will lead to more efficient homes, its effect is necessarily limited, unless it is also linked to additional policies. To generate truly significant savings a home energy rating disclosure policy will probably have to be coupled to a requirement that existing buildings meet a minimum home energy performance level. The city of Berkeley, California, for example, administers an ordinance that includes this requirement. Importantly, the Berkeley ordinance does not require improvements designed to make the residence meet code. Instead, it delineates a set of energy efficiency measures that must be installed, but also contains a cost ceiling that limits the number of required measures.

The following figure gives an example of the Energy Performance Certificate used in the European Union. It provides information on both the building energy use and its greenhouse gas emissions. The energy rating is done on a graduated scale from A to F supplemented by color coding to simplify the ability to interpret the label.

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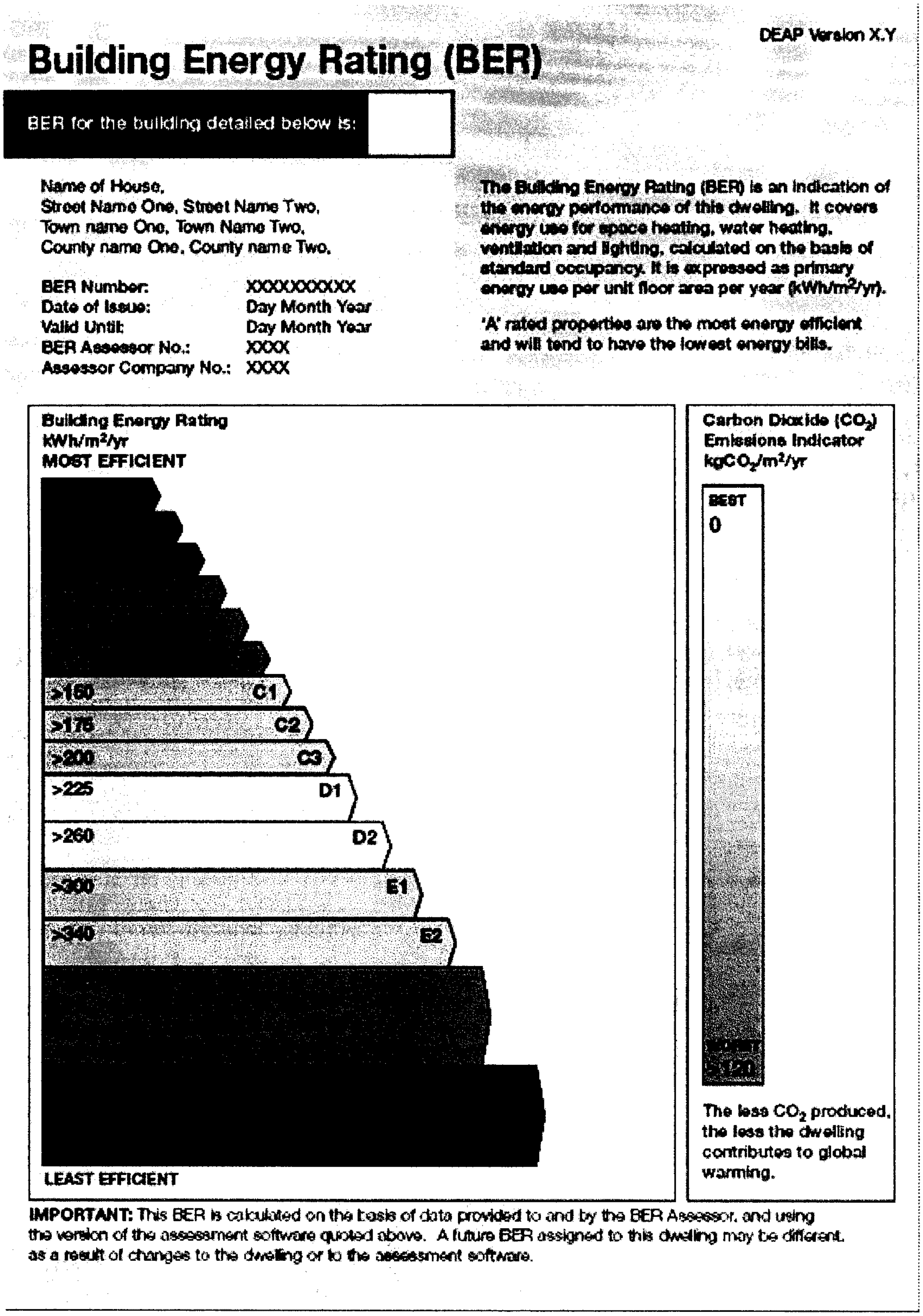
[26] To find a link to Energy Star Yardstick, go to: http://www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_index_tools

[27] The European Union directive allows member states to develop their own methodologies.



DEAP Version X.Y

Building Energy Rating (BER)

BER for the building detailed below is:

Name of House,
Street Name One, Street Name Two,
Town name One, Town Name Two,
County name One, County name Two,

BER Number:	XXXXXXXXXX
Date of Issue:	Day Month Year
Valid Until:	Day Month Year
BER Assessor No.:	XXXX
Assessor Company No.:	XXXX

The Building Energy Rating (BER) is an indication of the energy performance of this dwelling. It covers energy use for space heating, water heating, ventilation and lighting, calculated on the basis of standard occupancy. It is expressed as primary energy use per unit floor area per year (kWh/m²/yr).

'A' rated properties are the most energy efficient and will tend to have the lowest energy bills.

The less CO_2 produced, the less the dwelling contributes to global warming.

IMPORTANT: This BER is calculated on the basis of data provided to and by the BER Assessor, and using the version of the assessment software quoted above. A future BER assigned to this dwelling may be different, as a result of changes to the dwelling or to the assessment software.

Disclosure of Home Energy Use at Time of Sale Policy: Best Practices Examples

<table>
<tr><th>State</th><th>Directive/ Legislation</th></tr>
<tr><td>**European Union**</td><td>Article 7
Directive 2002/91/EC of the European Parliament and of the Council of 16 December, 2002 on the energy performance of buildings.
http://www.eco.public.lu/attributions/dg3/d_energie/energyefficient/info/directive_en.pdf</td></tr>
<tr><td colspan="2">**Summary:** This directive gives requirements on the use of Energy Performance Certificates (EPC) as part of a labeling requirement. The EPCs are given to the buyer at the time of sale.</td></tr>
<tr><td>**Nevada**</td><td>Chapter 509, 2007 Session
http://www.leg.state.nv.us/74th/Bills/SB/SB437_EN.pdf</td></tr>
<tr><td colspan="2">**Summary:** This statute gives requirements for disclosure. It, however, allows a transaction to occur without being subject to disclosure if both the seller and buyer agree to waive the requirements.</td></tr>
<tr><td>**Montgomery County, Maryland**</td><td>Bill No. 31-07
http://www.montgomerycountymd.gov/content/council/pdf/bill/2008/20080804_31-07.pdf</td></tr>
<tr><td colspan="2">Summary: This ordinance, which goes into effect on January 1, 2009, requires the disclosure of energy bill information over the preceding 12 months. The original legislative proposal actually required a HERS rating, but that provision was dropped prior to enactment.</td></tr>
<tr><td>**Berkley, California**</td><td>Chapter 19.16
http://www.ci.berkeley.ca.us/uploadedFiles/Clerk/Level_3_-_BMC/BMC-Part1-T1-22--120808.pdf</td></tr>
<tr><td colspan="2">**Summary:** This ordinance requires the seller of a property to install certain energy conservation measures such as (but not limited to) installing ceiling insulation, replacing incandescent light bulbs, and sealing ducts. The seller must receive a certificate of compliance prior to completing the sale.</td></tr>
</table>

Suggested Statutory Language: *The [relevant state agency- one having jurisdiction over consumer protection], in consulting with the [Authority Having Jurisdiction] shall develop requirements and adopt regulations for evaluating and disclosing the energy consumption of residential dwellings and commercial buildings at the time of sale of such dwellings and buildings.*

The regulations must include, without limitation: (a) standards for evaluating the energy consumption of the residential dwellings and commercial buildings, (b)

The seller of a property shall have the energy consumption evaluated per the program established by section xx prior to the sale of the dwelling. The [relevant state agency- one having jurisdiction over consumer protection] shall establish regulations for labeling or providing a readily accessible means of disclosure by the seller.

Subsection () does not apply to a sale or intended sale of residential property:

(a) Between any co-owners of the property, spouses or persons related within the third degree of consanguinity.

(b) By a person who takes temporary possession or control of or title to the property solely to facilitate the sale of the property on behalf of a person who relocates to another county, state or country before title to the property is transferred to a purchaser.

If an evaluation of a residential property was completed not more than 5 years before the seller and purchaser entered into the agreement to purchase the residential property, the seller may serve the purchaser with that evaluation.

2. Require Benchmarking for Commercial Buildings

Policy Recommendations:

a. State should require the energy performance benchmarking of all commercial buildings.
b. For benchmarking, the state should require the use of the EPA Portfolio Manager or equivalent.

Policy Explanation: Benchmarking consists of developing a record of the baseline energy use and rating of commercial buildings in order to develop data for comparison between comparable building types and sizes. Benchmarking can help guide the development of public policies that seek to maximize building energy efficiency, as well as to evaluate the efficacy of these policies. To properly develop benchmarks states need to gather data from commercial building owners and establish an easily accessible database that contains the energy consumption information.

An effective building energy codes policy requires the accurate accounting of building energy use to track the potential savings from implementing energy efficient codes and other state policies. By having access to the data provided by benchmarking, building owners, lenders and potential buyers can make informed decisions regarding building energy use. For example, a building owner could use the information to lower energy use and make the building more commercially attractive to buyers or tenants. A potential buyer, on the other hand, can use the information to press for improvements in energy use on the part of the current building owner. Benchmarking should also help policymakers achieve energy gains by tracking the progress of policies such as building energy codes.

It should be noted, however, that benchmarking can function as a building energy rating system such as the ones described in the previous section. However, it can differ in that it compares building energy use to similar buildings and therefore cannot tell how far along a building is toward a specific building energy related goal such as net zero energy status. When used effectively, benchmarking and building energy rating systems can complement each other in moving toward a common goal of maximizing building energy efficiency.

Finally, benchmarking (much like home energy ratings) can help determine whether individual buildings comply with the state code as well as help track compliance across the state.

Integration with Programs: SBC energy efficiency programs can use benchmarking as a way of establishing a baseline from which to guide clients as to the most effective ways to reduce energy use. Some programs typically use benchmarking as among the first actions when working with customers.

Best Practices: A benchmarking policy should aim for the most comprehensive and accurate energy use data possible. The state of California, which mandates building energy benchmarking for non-residential buildings, employs the Environmental Protection Agency's Portfolio Manager (PM) as the basic database tool. The PM has the ability to provide summary reports on the full universe of buildings as well as subsets to help track energy use. PM does have limitations, however, as it is unable to cover the full universe of buildings.[28]

Any building benchmarking policy should include both publicly- and privately-owned commercial buildings. Publicly-owned buildings (state and local) should be addressed first to allow officials to work out any unforeseen problems that may potentially arise, such as difficulty in determining the extent of information required from a given property.

Unlike other building related policies that involve utilities as discussed in this paper, benchmarking requires the participation of both investor owned and municipal utilities. The participation of both is crucial to get complete coverage of the building stock in the state.

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[28] Portfolio manager only benchmarks those buildings that are included as part of Commercial Building Energy Consumption Survey (CBECS). The types of buildings include: banks/financial institutions, courthouses, hospitals, hotels, K-12 schools, medical offices, offices, residence halls, retail stores, supermarkets, warehouses, wastewater treatment plants.

A benchmarking policy should feature a system for ensuring that all stakeholders, buyers, owners and lenders have access to the gathered information; should offer easy identification of building types; and organize energy use data by month. The responsible agency or organization must also work with utilities to create the appropriate disclosure forms that will provide the necessary information and protect the confidentiality of customer information.

Just as with commissioning, benchmarking is a part of SBC programs in some states as well as actual policy in California and the District of Columbia. This means that benchmarking is not a "new", untested policy but that many of the stakeholders already have experience implementing the policy and therefore, there is already a level of market expertise.

Finally, state policy should seek to tie policies such as retro-commissioning [29] to benchmarking. By using benchmarking, a building's actual use can be compared to its predicted energy use. Consequently, the use of retro-commissioning can help reduce discrepancies between a building's predicted energy use and its measured energy use.

Benchmarking Policy: Best Practices Examples

State	Statute
California	Section 25402.10 of the Public Resources Code (Enabling Language) http://www.leginfo.ca.gov/cgi-bin/displaycode?section=prc&group=25001-26000&file=25400-25405.6
Summary: This statute requires electric and gas utilities, as defined, on and after January 1, 2009, to maintain records of the energy consumption data of all nonresidential buildings to which they provide service. The statute would require, on and after January 1, 2010, that a non-residential building owner or operator disclose ENERGY STAR Portfolio Manager benchmarking data and ratings, for the most recent 12-month period, to a prospective buyer, lessee, or lender.	
Washington D.C.	Clean and Affordable Energy Act of 2008 http://www.dccouncil.washington.dc.us/images/00001/20080804150618.pdf

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[29] Retro-commissioning refers to the practice of commissioning a building after it has been in operation for a certain period of time. It is a particularly useful practice if evidence, such as from benchmarking, indicates that the building is not meeting energy performance goals. Because retro-commissioning is done to an operational building, the commissioning is much more likely to identify and correct the problems tha t are hindering energy performance.

Summary: The statute will first require the benchmarking, using the ENERGY STAR Portfolio Manager tool, for all city buildings greater than 10,000 square feet. Starting in 2010 until 2013, the city will require energy use information for all private buildings between 50,000 and 200,000 square feet to benchmark these buildings.	
Massachusetts Department of Energy Resources	Energy Information Reporting System http://www.mass.gov/Eoeea/docs/doer/gca/energy-information-reporting-system.pdf
Summary: The state energy agency has implemented a voluntary reporting system to help cities and towns implement energy management initiatives. The reporting system provides a means for cities and towns to benchmark their municipal buildings and therefore monitory and verify the energy performance of their buildings.	

Suggested Statutory Language: *(a) On and after January 1, 20XX, electric and gas utilities shall maintain records of the energy consumption data of all nonresidential buildings to which they provide service. This data shall be maintained, in a format compatible for uploading to the United States Environmental Protection Agency's ENERGY STAR Portfolio Manager or similar system, for at least the most recent 36 months.*

(b) On and after January 1, 20XX, upon the written authorization or secure electronic authorization of a nonresidential building owner or operator, an electric or gas utility shall upload all of the energy consumption data for the account specified for a building to The ENERGY STAR Portfolio Manager. The electric or gas utility shall maintain information in a manner that preserves the confidentiality of the customer.

(c) In carrying out the requirements of this section, an electric or gas utility may use any method for providing the specified data in order to maximize efficiency and minimize overall program cost, and is encouraged to work with EPA and customers in developing reasonable reporting options.

(d) On and after January 1, 20XX, an owner or operator of a nonresidential building over 10,000 square feet shall disclose the ENERGY STAR Portfolio Manager benchmarking data and ratings for the most recent 24-month period to a prospective buyer, lessee of over 2,000 square feet of the building, or lender that would finance over 2,000 square feet of the building. On and after January 1, 20XX, an owner or operator of a nonresidential building over 10,000 square feet shall annually disclose the ENERGY STAR Portfolio Manager benchmarking data and ratings for the most recent 24-month period to lessees of the building. If the data is delivered to a prospective buyer, lessee, or lender, a property owner, operator, or their agent is not required to provide additional information, and the

information shall be deemed to be adequate to inform the prospective buyer, lessee or lender regarding ENERGY STAR Portfolio Manager benchmarking data and ratings for the most recent 24-month period for the building that is being sold, leased, financed, or refinanced.

(e) Notwithstanding subdivision (d), nothing in this section increases or decreases the duties, if any, of a property owner, operator, or his or her broker or agent under this chapter or alters the duty of a seller, agent, or broker to disclose the existence of a material fact affecting the real property.

(f) Beginning one year after the effective date of this Act all nonresidential buildings over 10,000 square feet owned or operated by the ______ government or any of its instrumentalities shall be publicly benchmarked annually using the Energy Star Portfolio Manager benchmarking tool.

(g) All privately-owned nonresidential buildings shall be benchmarked annually using the Energy Star Portfolio Manager benchmarking tool as designated by the schedule in paragraph

(h) of this subsection; benchmarking data and ratings for the most recent 24-month period each building shall, by January 1 of the following year, be made available to [government agency]. [Government agency] shall, upon the receipt of the 2nd annual benchmarking data for each building, make the data accessible to the public via an online database.

(i) The schedule shall be as follows:
(A) All buildings over 150,000 square feet of gross floor area beginning in 2011 and thereafter; (B) All buildings over 50,000 square feet of gross floor area beginning in 2012 and thereafter.

(j) A project that has submitted the first construction building construction permit after January 1, 2011, for new construction or substantial improvement shall, prior to construction, estimate its energy performance using the Energy Star® Target Finder Tool and shall subsequently be benchmarked annually using the Energy Star® Portfolio Manager benchmarking tool; provided, that the building is over 10,000 square feet. Benchmark and Target Finder ratings and data for each building shall, within 60 days of being generated, be made available to [government agency], which shall make the data accessible to the public via an online database.

4. Conclusion

Progressive building energy codes and other public policies related to energy codes provide an important means for reducing energy use in the Northeast. Pursuing a comprehensive building energy codes policy will result in codes that are more energy efficient, more buildings that comply with code and more effective tools to measure and verify the energy savings that occur.

Energy efficient buildings result in multiple benefits: financial savings that accrue to both owners and occupants; fewer emissions of greenhouse gases, and less stress on the electricity grid. It cannot be emphasized enough that newly-constructed and substantially renovated buildings represent a limited window of opportunity to either ensure substantial energy, environmental and economic savings for years to come, or miss that opportunity and live with buildings and homes that are wasteful and inefficient. Lack of a strong building energy code policy will permit buildings to use more energy than they should, to saddle occupants with unnecessary and unpredictable costs, and to make compliance with aggressive air quality and climate change policies much more difficult. It is NEEP's hope that this Model Progressive Building Energy Codes Policy will help states recognize that opportunity and act upon it in a way that supports the construction of more efficient, sustainable and affordable homes and buildings across the Northeast.

5. Appendices

D. Potential Energy Savings and Potential Reductions in Carbon Emissions Resulting From More Efficient Building Energy Codes

The following four tables highlight the energy and environmental benefits of improving energy codes in the Northeast. Tables 1 and 2 show potential energy savings in the residential and commercial sectors, respectively, while Tables 3 and 4 show the potential carbon dioxide emissions avoided in those same sectors.

The levels of code improvement in these tables coincide with the major policy aims established by agencies such as the U.S. Department of Energy. The DOE has made the improvement of the national model code (2006 Edition of the IECC and the ASHRAE 90.1-2004) by 30 percent (toward the eventual realization of net-zero energy buildings) as an explicit policy goal. The next milestone for which code savings are analyzed - 70 percent more efficient than the 2006 IECC - is derived from the DOE defined target of 70 percent energy savings necessary to attain net zero energy building status, with the remaining energy to attain neutrality resulting from on-site or building-integrated renewable energy mechanisms.

To give a basis of comparison, the average home in New England uses approximately 120 million BTUs of energy per year. Therefore, the Massachusetts energy savings in 2011, for example, are equivalent to the energy consumption of 1,600 New England households. By 2050, the annual energy savings total about 135,000 households.

An average automobile emits roughly 12,100 lbs of carbon dioxide per year. Therefore, the avoided annual carbon dioxide emissions in 2050 in the Northeast roughly equates to removing over 16 million cars off the road. (See Figure 6)

Table 1

Energy Savings from Implementation of Improved Residential Energy Codes in Northeast States[30] (Trillion BTUs)

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Connecticut	0.38	3.42	11.93	0.33	12.73	6.06	26.10
District of Columbia	0.04	0.32	1.13	0.03	1.20	0.57	2.47
Delaware	0.21	1.87	6.53	0.18	6.96	3.32	14.28
Maine	0.57	5.05	17.60	0.49	18.76	8.94	38.48
Maryland	0.94	8.38	29.22	0.81	31.16	14.84	63.90
Massachusetts	0.19	1.70	5.94	0.16	6.34	3.02	13.00
New Hampshire	0.22	1.98	6.90	0.19	7.36	3.50	15.09
New Jersey	1.10	9.80	34.17	0.94	36.44	17.35	74.72
New York	1.41	12.59	43.89	1.21	46.80	22.29	95.98
Pennsylvania	1.30	11.53	40.21	1.11	42.88	20.42	87.93
Rhode Island	0.08	0.71	2.49	0.07	2.65	1.26	5.44
Vermont	0.67	5.93	20.67	0.57	22.04	10.50	45.20
Total	**7.11**	**63.29**	**220.69**	**6.10**	**235.32**	**112.07**	**482.59**

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[30] The totals for Tables 1-4 come from computer models developed by the Building Codes Assistance Project.

[31] As noted earlier, the 30 percent improvement occurs in 2011 and the 70 percent improvement occurs in 2020.

Table 2

Energy Savings from Implementation of Improved Commercial Energy Codes in Northeast States (Trillion BTUs)

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Connecticut	0.57	5.21	19.10	0.61	20.52	13.11	49.69
District of Columbia	0.24	2.21	8.09	0.26	8.69	5.55	21.04
Delaware	0.37	3.37	12.35	0.39	13.26	8.48	32.13
Maine	1.00	9.09	33.35	1.06	35.81	22.89	86.75
Maryland	1.33	12.10	44.40	1.41	47.69	30.47	115.50
Massachusetts	0.29	2.61	9.59	0.30	10.30	6.58	24.95
New Hampshire	0.34	3.12	11.43	0.36	12.28	7.85	29.74
New Jersey	2.06	18.72	68.69	2.18	73.77	47.14	178.68
New York	3.08	28.09	103.06	3.27	110.68	70.73	268.09
Pennsylvania	1.91	17.43	63.95	2.03	68.68	43.89	166.35
Rhode Island	0.12	1.09	4.00	0.13	4.30	2.75	10.41
Vermont	0.10	0.90	3.30	0.10	3.55	2.27	8.59
Total	**11.41**	**103.94**	**381.31**	**12.09**	**409.52**	**261.69**	**991.92**

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[32] As noted earlier, the 30 percent improvement occurs in 2011 and the 70 percent improvement occurs in 2020.

Table 3

Carbon Dioxide Emissions Avoided Through Improvements in Residential Energy Code in Northeast States (million metric tons)

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Connecticut	0.02	0.22	0.75	0.02	0.80	0.38	1.64
District of Columbia	0.00	0.02	0.07	0.00	0.07	0.03	0.14
Delaware	0.01	0.11	0.38	0.01	0.41	0.19	0.84
Maine	0.04	0.32	1.10	0.03	1.18	0.56	2.42
Maryland	0.06	0.48	1.70	0.05	1.82	0.87	3.74
Massachusetts	0.01	0.11	0.37	0.01	0.40	0.19	0.82
New Hampshire	0.01	0.12	0.43	0.01	0.46	0.22	0.95
New Jersey	0.06	0.57	1.99	0.06	2.13	1.02	4.37
New York	0.08	0.67	2.40	0.07	2.63	1.25	5.38
Pennsylvania	0.08	0.67	2.34	0.07	2.51	1.20	5.15
Rhode Island	0.01	0.05	0.16	0.00	0.17	0.08	0.34
Vermont	0.04	0.37	1.29	0.04	1.39	0.66	2.84
Total	**0.42**	**3.70**	**12.98**	**0.36**	**13.97**	**6.65**	**28.65**

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[33] As noted earlier, the 30 percent improvement occurs in 2011 and the 70 percent improvement occurs in 2020.

Table 4

Carbon Dioxide Emissions Avoided Through Improvements in Commercial Energy Code in Northeast States (million metric tons)

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Connecticut	0.03	0.24	0.86	0.03	0.95	0.61	2.30
District of Columbia	0.01	0.11	0.43	0.01	0.46	0.30	1.12
Delaware	0.02	0.18	0.65	0.02	0.71	0.45	1.71
Maine	0.05	0.43	1.50	0.05	1.66	1.06	4.01
Maryland	0.07	0.63	2.35	0.07	2.54	1.62	6.15
Massachusetts	0.01	0.12	0.43	0.01	0.48	0.30	1.15
New Hampshire	0.02	0.15	0.51	0.02	0.57	0.36	1.38
New Jersey	0.11	0.97	3.63	0.12	3.93	2.51	9.52
New York	0.13	1.21	4.71	0.16	5.38	3.44	13.04
Pennsylvania	0.10	0.91	3.38	0.11	3.66	2.34	8.86
Rhode Island	0.01	0.05	0.18	0.01	0.20	0.13	0.48
Vermont	0.00	0.04	0.15	0.00	0.16	0.10	0.40
Total	**0.56**	**5.03**	**18.78**	**0.61**	**20.70**	**13.23**	**50.13**

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[34] As noted earlier, the 30 percent improvement occurs in 2011 and the 70 percent improvement occurs in 2020.

E. Glossary of Terms relating to Building Energy Codes

Following is a list of terms that are commonly used in relation to building energy codes.

Administrative Amendment: A change to a model code requirement that brings the adopted regulation into compliance with state and/or local laws.

Adopting Authority: The agency or agent that adopts the energy code in a state.

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE Standard 189.1: An ASHRAE standard for minimum requirements for sustainable construction. Standard 189.1 aims for a 30% improvement in energy efficiency over ASHRAE 90.1-2004

ASHRAE/IES Standard 90.1-2007: The latest American Society of Heating, Refrigerating and Air-Conditioning Engineers/Illumination Engineering Society Standard for construction of commercial buildings.

ASHRAE/IES Standard 90.1-2004: The ASHRAE Standard that has been adopted by most states in the Northeast. Every northeast state except Massachusetts and Delaware currently enforces this standard.

Building Codes Assistance Project [BCAP]: Organization that assists states in adoption and implementation of energy codes.

Building Energy Code: Minimum requirements for the building envelope, mechanical systems and lighting for energy efficiency/conservation.

Building Inspector: The official responsible for the compliance of construction documentation with the adopted building codes.

Building Official: The officer or his designated representative authorized to act on behalf of the authority having jurisdiction.

COMCheck: Department of Energy compliance software for energy conservation in buildings other than low-rise residential buildings.

Energy Performance Rating: The energy use of the proposed building under actual operating conditions. Projected energy use targets can be used for buildings in the design or construction process. Examples include kBTU/sf/yr, dollars/square foot/yr, dollars/gross sales, Energy Performance Rating Score (US EPA), or like expressions of energy performance.

HERS Index: The HERS Index is a scoring system established by the Residential Energy Services Network (RESNET) in which a home built to the specifications of the HERS Reference Home (based on the 2006 International Energy Conservation Code) scores a HERS Index of 100, while a net zero energy home scores a HERS Index of 0. The lower a home's HERS Index, the more energy efficient it is in comparison to the HERS Reference Home. Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference Home.

Home Energy Rating Service [HERS}: HERS provide a standardized evaluation of a home's energy efficiency and expected energy costs.A home energy rating involves an analysis of a home's construction plans and onsite inspections. Based on the home's plans, the Home Energy Rater uses an energy efficiency software package to perform an energy analysis of the home's design. This analysis yields a projected, pre-construction HERS Index.

I-Code Family: The compendium of separate, integrated model building codes published by the International Code Council and which include codes that govern energy use. .

ICAA: Insulation Contractors Association of America.

ICC: International Code Council

IEBC: International Existing Building Code

IECC: The International Energy Conservation Code formerly known as the Model Energy Code. The IECC was published in 1998, 2000, 2003, and 2006 with amendments adopted in the intervening years. The IECC is on an eighteen month cycle.

IRC: The International Residential Code. This code covers one and two family dwellings, including attached townhouses.

NCSBCS: The National Conference of States on Building Codes and Standards members include state code administrators and officials.

NEBCA: The Northeast Building Code Association, an organization founded in New England in 1966 to promote adoption of uniform building codes throughout the region.

NFRC: National Fenestration Rating Council. Adopts standards for window and door performance.

NWWDA: National Wood Window and Door Association.

Performance Approach: A performance approach (also known as a systems performance approach) compares a proposed design with a baseline or reference design and demonstrates that the proposed design is at least as efficient as the baseline in terms of annual energy use. This approach allows the greatest flexibility but may require considerably more effort. A performance approach is often necessary to obtain credit for special features such as a passive solar design, photovoltaic cells, thermal energy storage, fuel cells, and other nontraditional building components. This approach requires an annual energy use value. There are several commercially available software tools that perform this analysis.

Prescriptive Approach: A prescriptive approach lists minimum R-value/maximum U-factor requirements for building envelope components, such as windows, walls, and roofs. It lists lighting systems prescriptive performance in commercial buildings as the allowable watts per square foot of interior space for various building uses. Minimum required equipment efficiencies for mechanical systems and equipment are not prescriptive by code, but by Federal standards.

RECA: The Responsible Energy Codes Alliance, dedicated to adoption of the latest energy conservation codes by all jurisdictions with no technical amendments.

RESCheck: Department of Energy compliance software for energy conservation in low-rise residential buildings, including detached residences and townhouses.

Technical Amendment: A revision or waiver of a building quality, efficiency or performance standard requirement in a model code.

Third Party Inspectors: Qualified, approved inspection agencies and individuals responsible for inspection of specialized construction work under the authority of an approved design professional in responsible charge of a special inspections program.

Time-of -Sale Energy Code Requirements: A local law setting either a reporting or energy upgrade requirement on transfers of property.

Trade-Off Approach Energy efficiency compliance achieved for an entire building or structure by allowing decreased energy efficiency in one component against increased efficiency in another component, thereby offsetting each other and maintaining a prescribed level of efficiency/energy loss. These trade-offs typically occur within major building systems (e.g. envelope, mechanical) or in commercial lighting, but may not be allowed between systems unless by exception.

Northeast Energy Efficiency Partnerships

REGIONAL EM&V METHODS AND SAVINGS ASSUMPTIONS GUIDELINES

A Product of the Regional Evaluation, Measurement & Verification Forum

May 2010

Facilitated and Managed by Northeast Energy Efficiency Partnerships

Table of Contents

PREFACE

Regional EM&V Methods & Assumptions Guidelines

Background and Purpose: These Regional Evaluation, Measurement and Verification (EM&V) Methods & Assumptions Guidelines ('the Guidelines') were prepared for the Regional EM&V Forum ('the Forum'). The Forum, established in 2008, is a regional project facilitated and managed by Northeast Energy Efficiency Partnerships (NEEP) representing states in New England[1], New York, New Jersey, Maryland, Delaware, and the District of Columbia.

The intent of these guidelines is to provide clarity, transparency, and a common understanding of methods to consider in determining gross energy and demand savings, and savings assumptions for a priority set of energy efficiency program/project types or measures. The Forum initiated this project because it is believed that some form of EM&V guidance, if implemented and used, can provide the following benefits to the Region:

- Improve the credibility and comparability of energy efficiency resources to support state and regional energy, climate change and other environmental policy goals;
- Remove barriers to the participation of energy efficiency resources in regional markets by making EM&V practices and savings assumptions more transparent, understandable and accessible;
- Reduce the cost of EM&V activities by leveraging resources across the region for studies of common interest (where a need for new data has been identified); and
- Inform the potential development of national EM&V protocols.

Basis for Guidelines: The Guidelines are based on research that captures existing EM&V methods used in the industry today[2]. They are presented in the format of cross-cutting recommendations that are applicable to fourteen measures/programs (covering topics such as rigor, site inspections and measure life determination), and in the form of measure specific recommendations. The Guidelines recommend basic EM&V methods, and alternative or additional approaches for conducting EM&V which Forum participants can use independently for any one program/measure type, and/or in combination, depending on the specific energy efficiency project, program or portfolio objectives.

The Guidelines are also based on a review and comparison of savings input assumptions and algorithms for the set of measures/programs. The Guidelines recommend and provide commentary on: where greater consistency on certain savings assumptions makes sense; where consistency is neither appropriate nor warranted; and where better documentation (or

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[1] Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont.

[2] The Guidelines are based on the EM&V Forum project *Develop Common EM&V Methods and Savings Assumptions* conducted by KEMA Consulting, April 2010. To view full report, see http://neep.org/emv-forum/forum-products-and-guidelines.

new research) is needed to support savings assumptions, in particular those that are deemed or stipulated.

Use of Guidelines: The Guidelines are not intended to be mandatory, as it is recognized that identical EM&V requirements and practices may be difficult to implement for the entire Forum Region given states or jurisdictions can have different program and EM&V objectives, budgets, and uses for their EM&V analyses. As such, these guidelines attempt to capture an appropriate balance of being flexible and not overly prescriptive, while providing sufficient detail so as to be meaningful and useful so that the Region can move towards greater consistency in how energy efficiency savings are determined.

The Guidelines are intended only to guide the design of comprehensive studies that estimate multiple impact parameters for one of the fourteen measures addressed in this report - *once a determination has been made to conduct such a comprehensive study*. The Guidelines should not be interpreted as suggesting that such comprehensive studies are always desirable, should be conducted with any particular frequency or should be routinely integrated into annual savings verification procedures. Decisions on when such comprehensive studies should be conducted will necessarily be based on local factors, including local trade-offs between the benefits of additional accuracy of savings estimates and the cost of such studies.

The Guidelines are also not necessarily applicable to studies intended to focus only on individual parameters or subsets of parameters. Further, the Guidelines do not make recommendations regarding transferability of evaluated results from one service territory to another within a state or region. While use of secondary data is generally accepted within the Forum region as a means to reduce evaluation costs (including for certain Forum projects e.g., commercial lighting loadshape study), validity implications of data transferability have yet to be explicitly and consistently addressed. It is recommended that the Forum develop guidelines on the transferability of evaluation results and review evaluation cycles to help ensure that the results are valid, appropriate, and reasonable.

Evaluators, program administrators, policymakers and others are encouraged to refer and use these recommended Guidelines, along with other Forum products on common EM&V terminology and common reporting formats, and to make suggestions for improvements and/or changes going forward. These Guidelines, as such, are viewed as a living document, and may lead to future projects that expand the measures/programs covered beyond those included herein. Additional efforts may also include exploring how the Forum's efforts, with respect to consistency, can support or perhaps even lead to similar efforts in other regions and nationally as efficiency becomes an increasingly greater strategy in energy and climate change mitigation efforts.

A special thanks is noted to this project's subcommittee members for their input and guidance in the development of these Forum guidelines: Gail Azulay, Mary Cahill, Alexey Cherniack, Gian DeLuca, Niko Dietsch, Helen Eisenfeld, Victoria Engel-Fowles, Kristy

Fleischmann, Gene Fry, Dimple Gandhi, Ruth Gay, Don Gilligan, Paul Horowitz, David Jacobson, Jeff King, Taresa Lawrence, Cathy Lezon, Huilan Li, Teri Lutz, Laura Magee, Erin Malone, Ed Miller, Josu Omaechevarria, Kim Oswald, David Pirtle, Ralph Prahl, Frederick Sackett, Jeff Schlegel, Mary Straub, Sheldon Switzer, Earle Taylor, Dave Weber, Lynn Westerlind, and John Zabliski.

The Project was managed by Julie Michals (NEEP), with Steve Schiller (Schiller Consulting) serving as project advisor.

Regional EM&V Methods and Savings Assumptions Guidelines

These Guidelines identify and define common and consistent methods for preliminary (ex-ante) savings, gross and net evaluated (ex-post) savings, measure baseline, life, and persistence, and strategies for dealing with uncertainty/rigor. The Guidelines cover the following program and technology types (fourteen in total)

Central A/C	Gas Boilers/Furnaces
Comprehensive Multi-Measure (R)	Lighting (Res)
Comprehensive Multi-Measure (NC)	Lighting (R)
Custom Measures (R/NC)	Motors (NC/TR)
Gas Boilers/Furnaces	Prescriptive Chillers (NC/TR)
HVAC (NC/TR)	Unitary/Split HVAC (NC/TR)
Lighting (NC)	VSDs (R/NC)

The Guidelines address each of the following EM&V elements:

- Estimating initial/preliminary gross energy and demand savings;
- Calculating gross evaluated energy and demand savings;
- Determining baseline conditions; and
- Determining measure life and persistence.

The first two elements are discrete for each of the fourteen electric and gas efficiency measures herein. For the latter two areas, Cross-Cutting Guidelines are provided.

1.1 Cross-Cutting Guidelines

This section presents guidelines for specific aspects of evaluation, measurement and verification practice that apply across the measures and are equally appropriate for all current and future measures that may be added to these guidelines.

1.1.1 Installation Verification

Verification refers to a program implementation process by which in-house staff or contracted inspectors verify the installation of all or a sample of installed measures. For most measures, this "quality control" procedure is performed prior to issuance of an incentive payment. This sort of verification is impractical for some small prescriptive and self-install measures, e.g. residential retail CFLs. In the context of evaluation, verification is a method of assessing impacts without direct measurement, e.g. phone surveys, on-site inspections, etc. Only when paired with measurement does verification become "M&V."

Verification of a sample of installations is highly recommended for all programs and measure categories. Verification incurs a cost, but as system reliability becomes more closely linked to energy efficiency resource performance, this cost provides increasing benefits. Assuming that payment of an incentive or proof of purchase equates to energy savings becomes riskier as the margins for error decrease.

Verification is often limited to projects/measures with the greatest cost and savings. When much is at stake in large projects, it is easier to verify to also justify the cost. However, some measures, such as compact fluorescent lamps, in aggregate can have an equivalent impact if not installed.

Installations should be verified by either a third party or by program administration staff. We emphasize that sampling approaches and regularly scheduled verification studies may be appropriate for some measures/programs instead of continuous verification for the full population. Procedures should be implemented to ensure that differences noted in inspection get reflected in program tracking. A higher verification fraction is recommended in program infancy, very large installations, or following substantive program revisions.

1.1.2 Determining Baseline Conditions

Within each of the measure-specific guidelines below there is a definition for the measure's baseline efficiency, a critical input into the savings calculation. In its simplest formulation, the savings forecast is the difference between what is (the baseline) and what will be (the intended condition). From there it gets more complicated. The baseline for a specific measure is not a single number.

For most measures there will be at least two baselines, one for market-driven choices (often called "lost opportunity" and either replacing equipment that has failed or new installations) and one for discretionary installations (often called retrofit or early retirement). In the first case, the baseline may be a jurisdictional code, a national standard, or the prevailing level of efficiency in the marketplace. For retrofit installations, the efficiency of the existing equipment may be the baseline, but at some point the savings calculation must incorporate changes to the baseline for new installations, e.g. code or market changes. Even at this level of differentiation, the baseline may not be correct.

A prime example of this phenomenon occurs when code is used as a baseline. The assumption that a legal requirement translates into action is foresworn by the full gamut of human behavior, even when there is enforcement to encourage compliance, as with speed limits. In the realm of efficiency, where compliance mechanisms often lag regulation and the "behavior" is much more private, it is even riskier to assume that the law is being followed.

It is recommended that a regular review of baselines in use be undertaken to determine and prioritize baseline research on a three to five year cycle. This process is critical to achieving, and maintaining, alignment between the conditions as they are and the conditions as they are used in savings calculations.

1.1.3 Determining Measure Life and Persistence

The measure-specific guidelines can be used to determine the savings for a discrete period of time. The capacity savings (kW) are instantaneous and calculated with reference to the maximum load. The energy savings (kWh) are typically presented for the first year. However, most measures last for more than one year.

Comprehensive guidelines should define a process for determining measure life for each measure, and then memorializing both the process and the outcome in comprehensive resources. While any of the methods currently used, e.g. vendor estimates & stipulated value, may be accurate, without structured review and analysis they may misrepresent actual performance. As for baseline conditions above, there should be a regular review cycle to assure that each measure lifetime assumption is not so old as to be out of date. A full measure life study is not needed for each measure every three or five years. Rather, an intentional process to determine if a study is appropriate is recommended.

Temporal factors “persistence” and “in-service rate” are not uniformly used. Some use these factors, some report them as incorporated in the measure life, and in some cases it is not clear if they are addressed. Measure life should be defined to include these factors if they are deemed necessary by the Forum or by external stakeholders, and should be considered in the design of measure life research.

1.1.4 Statistical Precision

The matter of quantifying the statistical precision of a composite domain such as an energy-efficiency portfolio is a complex one, and analytical consultants can assist with this process. One of the practical implications is that the statistical precision for dominant measures/sectors can ‘carry’ one’s portfolio, i.e. ensure the portfolio achieves precision targets regardless of the precision in other program areas. In a strictly statistical sense, the level of precision for dominant program areas such as Large C&I Retrofit or Residential Lighting tends to be far more important than the precision of lesser areas such as HVAC tune-ups or ENERGY STAR Appliances. In fact, the statistical precision of ‘minor’ portfolio components can remain immaterial even with assumed ±100% precision.

Program administrators must also consider that statistical precision in impact evaluation is not solely a matter of regulatory and capacity market rules compliance. Statistical precision is an important means of expressing the validity of estimated tracking and evaluation impacts. Further, one must remember that statistical precision often positively correlates with evaluation cost. This is true because sample size increases with statistical precision, and for each sample point that improves statistical precision there is an added burden of evaluation cost (i.e. added travel costs, monitoring equipment, interviews etc.). Despite increased rigor from capacity market rules, sample designs must remain efficient and optimized to achieve appropriate precision at a reasonable cost.

Recommendations: In order to establish and achieve statistical precision objectives in all required/sought dimensions, the following process should be considered:

1. Identify statistical confidence/precision requirements. These should include key requirements (e.g. capacity market specifications) and legacy objectives (e.g. 90/10 for annual energy savings). Also, establish the domain for each requirement, be it the portfolio, program, state, load-zone, etc.
2. Establish your unique precision targets and dimensions. Regulatory and market requirements may offer program administrators either a threshold or a range of confidence intervals and precision. In either case, program administrators may make an independent assessment of the precision targets that are necessary for their particular needs relative to the domain of the evaluation (i.e. sector, program, end use), their intended use and audience for the evaluation results, and considerations of expected variability and the financial or system impact of varying degrees of uncertainty.
3. Pursue the most challenging target. In most cases, statistical objectives will be multi-pronged, e.g. 80/10 for summer kW, 80/10 for winter kW, and 90/10 for energy kWh. Designing a single sample to meet all objectives can be difficult and is dependent upon the unique population characteristics and expected variability for each parameter. In practice, one often can achieve all objectives by pursuing the element with the greatest variability; for New England large C&I programs, this tends to be the winter coincident demand impact. For example, a recent KEMA large C&I impact evaluation achieved ±10.6% precision for winter kW and ±8.2% precision for summer kW (both at 80% confidence as per ISO New England requirements) and ±4.7% precision at the 90% confidence level.

It is important to note that these confidence/precision requirements are for statistical sampling alone and do not reflect other sources of uncertainty such as measurement error, equipment accuracy, and parameter bias. Most M&V manuals (ISO New England, PJM Interconnection, Federal Energy Management Program (FEMP), American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)) include guidelines for controlling these other sources of error.

1.1.5 Other Sources of Uncertainty and Threats to Validity

Statistical precision gets a lot of attention in efficiency program evaluation. Most evaluators are familiar with error bounds, confidence intervals, and relative precision, the most commonly used techniques for reporting statistical precision. However, many do not realize that statistical precision can be misleading if there is bias or non-statistical error in the underlying data. Bias can be hard to identify and extremely difficult to quantify, but it ought not be ignored or dismissed. One must remain vigilant for sources of error such as response bias, hand-picked (or excluded) sample projects, and measurement error. The California Evaluation Framework offers some good advice on mitigating bias and strengthening validity:

"In a high quality evaluation, those implementing the study would strive to mitigate the risk of bias and to honestly report any circumstances about the study that might increase the likelihood of bias. Unfortunately, it usually takes extra time and money to reduce the risk of bias, and the usual measures of the statistical precision of the results may not be improved at all. For example, in order to reduce the risk of non-response bias in a telephone survey, a substantial investment may be needed in more extensive training for the surveyors, more call backs, and perhaps to offer a financial incentive to each respondent. It may be tempting to accept a higher non-response rate and divert these resources to a larger sample size since this strategy will almost certainly give a narrower confidence interval. This strategy can seriously compromise the integrity of a study. To make appropriate judgments in planning and executing sound evaluation studies and in interpreting their results, evaluators, reviewers, and those using evaluation results need to understand what bias is, how it can arise, and how it can undermine an evaluation study."[3]

In sections on Statistical Significance, both the ISO New England and PJM Interconnection M&V manuals require Project Sponsors to describe methods for mitigating and controlling bias in demand estimates. These manuals list many sources of potential bias beyond statistical precision. According to these manuals, relevant types of potential bias for estimates based upon engineering and direct measurement include but are not limited to:

- accuracy and calibration of the measurement tools;
- measurement error;
- engineering model bias;
- modeler bias;
- deemed parameter bias;
- meter bias;
- sensor placement bias; and
- sample selection bias or non-random selection of equipment and/or circuits to monitor.

For estimates based upon regression or statistical analysis, relevant types of potential bias include but are not limited to:

- model misspecification;
- statistical validity;
- error in measuring variables;
- autocorrelation;
- heteroscedasticity;

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[3] *The California Evaluation Framework*, Chapter 12: Uncertainty, January 2006, p. 290.

- collinearity;
- outlier data points; and
- missing data.

For estimates based upon survey or interview data, relevant types of potential bias include but are not limited to:

- construct validity;
- sampling frame versus population;
- selection bias (for a sample and for a census attempt where not all sites within the census received usable data);
- non-response bias;
- error in measuring variables;
- sample homogeneity relative to project (external validity);
- outlier data points; and
- missing data.

Beyond a few vocal experts and advocates, the evaluation community is only beginning to grasp the importance and implications of these sources of uncertainty. The Forum is calling for a more balanced treatment of the true sources of uncertainty bearing on evaluation results, and this brief overview draws attention to the vast number of threats to validity beyond statistical precision.

1.2 Measure-Specific Guidelines

This section presents guidelines for fourteen measures or program types. The measure specific recommendations use a concise, two-section format to present guidelines on the following issues:

- Estimation methods and savings assumptions for initial/preliminary gross energy and demand; and
- Recommended M&V methods for pursuing gross evaluated energy and demand.

The first piece of each guideline presents the prevailing savings algorithm with a listing of inputs and savings assumptions. The second piece of each guideline is a brief outline of recommendations pertaining to program tracking and recommended/alternative M&V methods. Tracking recommendations relate to the data management processes and systems employed to document and database the savings associated with energy efficiency program measure installations. These recommendations emphasize completeness of pre-evaluation "initial gross" and "net" estimates of energy and demand impacts. ***The recommended and alternative M&V methods correspond to the "Options" defined in either the ISO New England or PJM Interconnection M&V manuals.*** These regional capacity market M&V

requirements are the prevailing compliance concern in the Forum region, and are largely based on the International Performance Measurement and Verification Protocol (IPMVP).

Finally, while the following guidelines focus upon primary M&V research, the readers should be aware of a recent EM&V Forum effort[4] that investigated the usability and transferability of load shape data from other sources, i.e. secondary data. Many jurisdictions have expressed support for the use of secondary data for measures such as residential lighting. This is an emerging issue, and guidelines for applicability of evaluation results and/or demand savings have yet to be fully explored in the Northeast.

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[4] End-Use Load Data Update Project Final Report, Phase1: Cataloguing Available End-Use and Efficiency Measure Load Data, September 2009. Available at http://neep.org/emv-forum/forum-products-and-guidelines.

1.2.1 Residential Central Air Conditioning

Prevailing Algorithm for Energy and Demand:

kWh Saved = (Size in Btu/hr) x ($1/SEER_{baseline}$ - $1/SEER_{installed}$) / 1000 x (Full Load Cooling Hours)

kW Saved = (Size in Btu/hr) x ($1/EER_{baseline}$ - $1/EER_{installed}$) / 1000 x (Coincidence Factor)

Notes on Algorithm:

1. Some entities express unit size or cooling capacity in terms of "tons" of cooling, a unit of power equivalent to 12,000 Btu/hr but lacking accuracy due to nominal tonnage nomenclature.
2. Other algorithms use discrete estimates of load factor, diversity factor, and coincidence factor in place of a combined "coincidence" factor to account for all these effects. The product of the three discrete factors is equivalent to the single combined loading/diversity/coincidence factor.
3. Most Technical Reference Manuals (TRMs) cite "full load hours" or "equivalent full load hours" in their algorithm, but one TRM uses "cooling load hours" which separates the influence of electrical efficiency from the time term in the equation.

Description of Inputs:

Baseline Efficiency: Rated Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER) of baseline equipment as per established standard or baseline study. Approximately 13 SEER and 11 EER. "Early retirement" tracks either prorate the existing and new construction baselines over the measure life or assume 9 or 10 SEER for baseline.

Installed Efficiency: Rated SEER and EER of installed equipment as per Air-Conditioning, Heating, and Refrigeration Institute database. Approximately 14 SEER and 12 EER or refer to "Energy Star or higher".

Units of Cooling Capacity: Engineering units for cooling capacity in Btu/hr for accuracy and to ensure efficiency compliance.

Full Load Cooling Hours: The ratio of annual cooling unit energy to nameplate peak demand. Cooling hours should reflect localized climate conditions and be based upon technical research studies. With few exceptions, most states in the Forum region have distinct climate zones which warrant distinct estimates of cooling hours.

Demand Factors: Adjustments to rated demand for use in deriving coincident impacts; recommendation is to consolidate these discrete adjustments into one coincidence factor for each season, i.e. Summer and Winter. As with full load cooling hours, seasonal coincidence should reflect localized climate conditions and should be based upon technical research studies.

Loading: The ratio of peak observed to rated maximum load for a piece of equipment. A discrete factor to express equipment over sizing effects at the typical unit level.

Diversity: The ratio of the maximum combined demand to the sum of non-coincident demands across a group. A discrete factor which expresses the extent to which a group contributes to a combined maximum.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 70% to 100% across the regional TRMs.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. The winter coincidence factor should be 0% for residential central air conditioning.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Standardize on Btu/hr as the unit of cooling capacity in the interest of accuracy and compliance.
2. Include both SEER and EER in algorithms for the best expression of both seasonal and peak performance.
3. Consolidate load, diversity, and coincidence factors into single factor combining all peak coincidence drivers.
4. Document credible sources for all savings assumptions. Currently, not all savings assumptions are clearly documented, and TRMs ought to cite credible sources for all savings assumptions to improve methodological transparency.
5. Develop (or continue to use) localized assumptions for cooling hours and peak coincidence. Consistent assumptions used for cooling hours across some states may not be warranted due to climate zones.
6. Consider differentiating by home vintage and location in program estimates of full load cooling hours.

This category is limited to central air conditioning (CAC) installed as a stand-alone measure and excludes CAC installed through comprehensive new construction programs. This category does not include ENERGY STAR room air conditioners or "space cooling" measures.

Aspect	Detailed Approach	Comments
Program Tracking	<u>At a minimum</u>: initial gross energy and demand savings, as well as initial net impacts as applicable. <u>Additional</u>: number of installed units, unit capacity, baseline and installed efficiency, and full load cooling hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering can offer the most defensible approach to residential CAC programs.	Metering methods often include time-of-use loggers and spot power measurements.
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with metering that fully isolates the entire CAC system (Option B).	Metering would be interval kW measurements on both the outdoor compressor and indoor fan units.
	Billing analysis (Option C) can be a reasonable energy evaluation method for residential CAC at lower cost. Central AC tends to be rather evident in whole-premise metering, although other substantial electric loads can be an obstacle.	Billing analysis alone cannot quantify demand impacts.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at capturing measure interaction. While perhaps excessive for stand-alone CAC, simulation modeling is particularly appropriate for evaluating comprehensive cooling measures.	Metering would mirror Option B probably with whole premise interval kW and some temperature measurements.

1.2.2 Residential Comprehensive Multi-Measure Retrofit

Prevailing Algorithm for Energy and Demand:

No prevailing algorithm. These comprehensive retrofits are comprised of a wide variety of measures and technologies. Savings methods for the component measures are not well documented in TRMs.

Notes on Algorithm:

1. The various energy-efficiency vendors that deliver residential comprehensive multi-measure retrofit measures tend to employ in-house software for developing/reporting savings. While the vendors and software methods are approved by the program, the savings methods are not necessarily unified or consistent.
2. A detailed review of the algorithms and savings assumptions for the remaining component measures such as appliances, insulation, weatherization, and water heating necessitates an examination of each vendor's methods. Research is warranted in this area to promote methodological consistency.
3. Technical reference manuals tend not to document residential comprehensive multi-measure retrofits as an umbrella offering and do not provide sufficient data to facilitate a comparison of savings assumptions.

Description of Inputs:

Not available.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Some of the simpler, component measures within residential comprehensive retrofit programs - such as domestic hot water - lend themselves well to a stipulated savings approach.
2. For lighting measures, a calculated approach using stipulated parameters, e.g. wattage reduction and hours-of-use, offers consistency for connected demand impact and localized tuning for energy and coincident peak demand savings.
3. Administrators should require transparency and consistent savings methodologies across all vendors delivering residential comprehensive retrofits in a given program or state.
4. Given the differences in climate and demographics across the Forum region, it is appropriate for program administrators to continue to develop certain localized assumptions that reflect local characteristics such as lighting hours-of-use, coincidence factors, and market standard insulation levels.

[redacted]

This category encompasses comprehensive multi-measure retrofit installations in residential homes. Sometimes called "deep retrofits" or "home energy services", these measures are characterized by a whole-home approach which typically involves an audit followed by efficiency recommendations for multiple end uses and technologies. The comprehensive residential approach tends to be electric-centric but also may span fuel measures such as water heating, boilers, or furnaces.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: detail on individual measures, such as: air conditioner, heat pump, boiler/furnace, water heater quantities and sizes; baseline and installed equipment efficiencies; home square footage; insulation and weatherization actions.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with visual inspections, quality of installation assessments, interviews, and short-term metering for select measures. Simple engineering models of savings impacts.	Metering limited to time-of-use loggers on lighting and HVAC equipment supported by spot power measurements.
Alternative M&V Methods	A dual-fuel option is to pair the Option A approach with a billing analysis (Option C) of gas impacts. Diagnostic testing of HVAC equipment, blower door, and duct blaster tests can add rigor and certainty to savings for envelope measures.	Billing analysis alone cannot quantify demand impacts.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at capturing measure interaction. Particularly appropriate for comprehensive multi-measures.	Metering would pursue HVAC system and whole premise interval kW and possibly some temperature measurements.

1.2.3 Residential Natural Gas Boilers and Furnaces

[redacted]

Prevailing Algorithm for Energy and Demand:

Therms saved = (Size in Btu/hr INPUT) x ($1/AFUE_{baseline}$ - $1/AFUE_{installed}$) x (Full Load Heating Hours) / 100,000

Alternative Algorithm:

Therms savings = (Size in Btu/hr INPUT) x EFLHeff x (AFUEeff/AFUEbase - 1)/100,000

Where the size of the unit and EFLHeff is for the installed high efficiency unit

Notes on Algorithm:

1. Most Technical Reference Manuals (TRMs) cite "full load hours" or "equivalent full load hours" (EFLH) in their algorithm, but one TRM uses "heating load hours" which separates the influence of thermal efficiency from the time term in the equation.
2. One TRM adds a heating load factor to explicitly adjust for over-sizing of the heating unit.
3. One state's algorithm accounts for the size of the installed and baseline units separately, using a fixed baseline capacity of 91,000 Btu/hr to represent the "typical heating unit" based on a baseline study.

Description of Inputs:

Baseline Efficiency: Rated Annual Fuel Utilization Efficiency (AFUE) of baseline equipment as per established standard or baseline study. Efficiency depends upon program type (early replacement, time of replacement, or new construction) as well as equipment type. Prevailing AFUE baselines are 75% for steam boilers, 78%-80% for furnaces, and 80-83% for hot water boilers.

Installed Efficiency: Rated AFUE of installed equipment as per Air-Conditioning, Heating and Refrigeration Institute (AHRI) database. Approximately 82% for steam boilers, 85% for non-condensing hot water boilers, 90% for condensing hot water boilers, and 92% for furnaces or refer to "Energy Star or higher".

Operating Hours: The ratio of annual heating unit energy to nameplate peak demand. Heating hours should reflect localized climate conditions and be based upon technical research studies. With few exceptions, most states in the Forum region have distinct climate zones which warrant distinct estimates of heating hours.

Summer Coincidence Factor: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. The summer coincidence factor should be 0% for residential heating equipment.

Winter Coincidence Factor: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Currently, most regional TRMs do not specify coincidence factors for natural gas measures. Coincidence should reflect localized climate conditions and should be based upon technical research studies.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Programs should take credit for electric impacts associated with efficient furnace fans within the natural gas furnace measure.
2. States currently using a custom approach for "point of sale" residential gas furnace and boiler measures should consider a prescriptive approach using the prevailing savings algorithm described above.
3. Develop (or continue to use) localized assumptions for heating hours and peak coincidence. Consistent assumptions used for heating hours across some states may not be warranted due to climate zones.
4. Consider differentiating by home vintage and location in program estimates of heating hours.

This category is limited to residential natural gas boilers and furnaces and excludes: space heating equipment such as portable or room space heaters; electric or oil space heating equipment; and associated controls such as boiler reset controls. This category addresses stand-alone heating equipment and excludes natural gas boilers/furnaces installed through comprehensive new construction programs.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, unit capacity, baseline and installed efficiency, and full load heating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	Billing analysis (Option C) supported by telephone surveys or on-site inspections. Telephone surveys can be used to confirm installation and gather data on household demographics and other operational characteristics to support the billing analysis.	Billing analysis is only valid when the pre-existing (electric bills from the pre-retrofit period) is the appropriate baseline to be used in the impact analysis.
Alternative M&V Methods	Adding on-site inspections to the basic method above improves confidence in household characteristics and supports collection of equipment nameplate data. Basic short-term measurements (Option A) can be added on electrical support equipment such as furnace fans and boiler pumps to refine savings estimates.	Metering methods would include time-of-use CT loggers and spot power measurements.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is probably excessive for stand-alone gas heating but would be appropriate for evaluating measures in a comprehensive package.	Natural gas sub-meters can be installed to isolate the heating equipment from other end uses.

1.2.4 Residential Lighting

Prevailing Algorithm for Energy and Demand:

kWh Saved = $(\text{Quantity}_{\text{baseline}} \times \text{Watts}_{\text{baseline}}) - (\text{Quantity}_{\text{installed}} \times \text{Watts}_{\text{installed}})$ / 1000 × (Annual Hours)

kW Saved = $(\text{Quantity}_{\text{baseline}} \times \text{Watts}_{\text{baseline}}) - (\text{Quantity}_{\text{installed}} \times \text{Watts}_{\text{installed}})$ / 1000 x (Coincidence Factor)

Notes on Algorithm:

1. Some Technical Reference Manuals (TRMs) stipulate the wattage reduction, utilizing a common Quantity term and substituting a □Watts or kW/unit term for $(\text{Watts}_{\text{baseline}} - \text{Watts}_{\text{installed}})$ in the equation above.
2. For retail programs, an in-service rate (ISR) often is added to the gross savings algorithm to represent the percentage of rebated units that actually get used. Some entities presume 100% installation rate or account for ISR in a net savings adjustment.

Description of Inputs:

Baseline Fixture Quantity: The number of fixtures in the corresponding baseline. The same as **Installed Fixture Quantity** for one-to-one replacements.

Baseline Fixture Wattage: For CFLs, baseline is typically 3.4 times **Installed Fixture Wattage**. For other fixture/lamp types, baseline wattage obtained from lookup tables developed and refined by technical and baseline studies.

Installed Fixture Quantity: The number of installed fixtures.

Installed Fixture Wattage: The rated wattage of the installed fixture, inclusive of both lamp and ballast. Obtained from nameplate data.

Annual Hours: The number of operating hours for the fixture in a typical year. Depending upon the program delivery vehicle, this can be derived from site-specific information, research-based estimates of lighting hours by room type, or - for retail programs - assigned a typical whole-home estimate which reflects the uncertainty of the lamp location. Residential lighting lends itself well to shared hours-of-use studies.

Coincidence Factors: Adjustments to rated demand for use in deriving coincident impacts; recommendation is to consolidate the Diversity into the Summer and Winter coincidence factors.

Diversity: The ratio of the maximum combined demand to the sum of non-coincident demands across a group. A discrete factor which expresses the extent to which a group contributes to a combined maximum.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 9% to 35% across the regional TRMs.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors range from 5% to 100% across the regional TRMs.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. A calculated savings methodology would facilitate regional consistency better than stipulated savings. Demand reductions by lighting technology are logical stipulations as inputs, and a consistent algorithm would allow for localized tuning of hours and coincidence for savings impacts.
2. Direct install residential lighting programs in the region assign lighting hours by both room type and fixture type. Improved consistency would come from agreeing on one hours-of-use dimension - either room type or fixture type.
3. The majority of residential lighting programs factor the ISR into gross savings, while a few reflect this adjustment in net savings. Achieving regional consistency suggests inclusion of ISR as a gross effect.
4. Combine coincidence factor with diversity. This should help to address significant differences observed in winter coincidence factors.
5. Given demographic, geographic, program maturity, and behavioral differences in lighting usage across region, specific states/utilities should consider localized assumptions for lighting hours, peak coincidence, and HVAC interactive factors.

[redacted]

This category is limited to single-family residential lighting exclusive of specialty low-income and multi-family programs. These measures span new construction, retrofit, direct install, and retail lighting programs.

Aspect	Detailed Approach	Comments
Program Tracking	<u>At a minimum</u>: initial gross energy and demand savings, as well as initial net impacts as applicable. <u>Additional</u>: baseline quantity and wattage, installed quantity and wattage, location (as available), hours of use, in-service rate, HVAC interaction.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Complete "socket counts" by room and fixture type provide key data for impact evaluations, baseline studies, and hours-of-use studies. Questions on purchasing habits and "shelf" stock inform in-service rate research. Site visits with time-of-use lighting loggers are the most defensible approach to residential lighting programs.	Time-of-use lighting loggers on a sample of lamps and fixtures, typically by room type.
Alternative M&V Methods	An alternative method is to rely upon telephone surveys to obtain information such as socket counts, hours of use, and purchasing habits. Research has shows that verbal hours tend to be overstated, but this type of Verification (not true M&V) is considered reasonable rigor for certain applications.	Not literally M&V without measurement, but this may comply with ISO-NE/PJM "Option A" with well-documented stipulations.

1.2.5 C&I Comprehensive Multi-Measure New Construction

Prevailing Algorithm for Energy and Demand:

Technical reference manuals (TRMs) do not provide calculations or algorithms for commercial and industrial comprehensive multi-measures; each project is unique. Comprehensive projects are often directed towards large facilities and cover wide ranges of equipment, schedules, approaches, and measure interactions.

Notes on Algorithm:

1. Comprehensive multi-measures are akin to multiple, interactive custom measures, and custom measures do not have prevailing algorithms. Nonetheless, the fundamental approach is to characterize the full dynamics of energy usage for the baseline and installed conditions across all hours of the year.
2. Hourly building simulations are a popular method, however advanced 8,760 spreadsheets can model energy usage in a more transparent manner.
3. With regard to measure interaction, the sequence in which the multiple measures are assessed affects the total savings for the combined measures.

Description of Inputs:

Not applicable.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. It is not possible to anticipate all possible factors and assumptions that comprise comprehensive multiple measures. However, criteria when comprehensive measures are required should be established and stated clearly in technical program documentation.
2. Calculations using site-specific baselines, installed equipment, and savings assumptions provide the most appropriate and rigorous path to savings impacts. Establishing interactive requirements for custom multiple measures is essential in obtaining true energy and demand savings.
3. Comprehensive projects can be comprised of both custom and prescriptive measures, and interaction should be handled in such a way to avoid double counting. Interactive hierarchies should be developed to provide a uniform track to calculate and report savings.
4. Comprehensive measures are inherently unique and project-specific. Even if methodological consistency is pursued (e.g. using eQUEST models), each project should employ local weather and operational characteristics.

This category is limited to the installation of commercial and industrial comprehensive multi-measure new construction projects. The comprehensive and multi-measure category is not clearly defined or specifically mentioned in many of the TRMs. References to multiple measures are included in custom measure discussions.

Aspect	Detailed Approach	Comments
Program Tracking	<u>At a minimum</u>: initial gross energy and demand savings, as well as initial net impacts as applicable. <u>Additional</u>: savings by measure component; description of individual measures with, as applicable, unit quantities, sizes/capacities, baseline and installed efficiencies, and operating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	Calibrated simulation modeling (Option D) which is especially effective at capturing measure interaction. On-site data collection would gather parameters, specifications, and operational characteristics to inform the model.	Metering would include whole premise interval kW and some end use metering.
Alternative M&V Methods	A viable alternative would be on-site inspections with metering that encompasses the entire set of measures (Option B). A complex engineering spreadsheet model would capture the dynamics and interactions on an hourly basis. Less rigorous metering (Option A) could be performed if accuracy and validity is not a significant concern.	Metering would be interval kW measurements on all or select end use equipment.

1.2.7 C&I Natural Gas Boilers and Furnaces

Prevailing Algorithm for Energy and Demand:

Furnaces < 225 MBH and boilers < 300 MBH

Therms saved = (Size in Btu/hr INPUT) x ($1/\text{AFUE}_{\text{baseline}} - 1/\text{AFUE}_{\text{installed}}$) x (Full Load Heating Hours) / 100,000

Furnaces ≥ 225 MBH and boilers ≥ 300 MBH

Therms saved = (Size in Btu/hr INPUT) x ($1/\text{Efficiency}_{\text{baseline}} - 1/\text{Efficiency}_{\text{installed}}$) x (Full Load Heating Hours)/100,000

Alternative Algorithm

Therms savings = (Size in Btu/hr INPUT) x EFLHeff x (AFUEeff/AFUEbase - 1)/100,000

Where the size of the unit and EFLHeff is for the installed high efficiency unit

Notes on Algorithm:

1. The prevailing algorithm only employs Annual Fuel Utilization Efficiency (AFUE), however the Air-Conditioning, Heating and Refrigeration Institute (AHRI) limits the use of AFUE to furnaces under 225 MBH and boilers less than 300 MBH. Units above this size have efficiency ratings in thermal efficiency and combustion efficiency. Accordingly, the recommended algorithm above includes a distinct expression for units above this size threshold.
2. Most Technical Reference Manuals (TRMs) cite "full load hours" or "equivalent full load hours" (EFLH) in their algorithm, but one TRM uses "heating load hours" which separates the influence of thermal efficiency from the time term in the equation.

Description of Inputs:

Baseline Efficiency: Rated AFUE or thermal efficiency of baseline equipment as per established standard or baseline study. Prevailing AFUE baselines are 75% for steam boilers, 78% for furnaces, and 80 for hot water boilers.

Installed Efficiency: Rated AFUE of installed equipment as per AHRI database. Approximately 82% for steam boilers, 85% for non-condensing hot water boilers, 90% for condensing hot water boilers, and 92% for furnaces.

Operating Hours: The ratio of annual heating unit energy to nameplate peak demand. Heating hours should reflect localized climate conditions and be based upon technical research studies. With few exceptions, most states in the Forum region have distinct climate zones which warrant distinct estimates of heating hours.

Summer Coincidence Factor: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Most programs do not estimate peak coincidence for gas measures; however one TRM specifies a 12% summer coincidence factor for commercial gas heating equipment.

Winter Coincidence Factor: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Most programs do not estimate peak coincidence for gas measures; however one TRM specifies an 88% winter coincidence factor for commercial gas heating equipment. Coincidence should reflect localized climate conditions and should be based upon technical research studies.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. While there is reasonable consensus on savings calculation methodologies and assumptions for small commercial natural gas heating equipment, it may be appropriate to treat large commercial boilers as custom measures. States currently using or considering a custom approach for small commercial gas heating equipment might consider a prescriptive approach under a given size threshold.
2. Differing limits placed on eligible capacities throughout the region may pose a barrier to greater consistency for commercial natural gas boiler and furnace measures. In two states, boiler capacity is used to determine whether a measure is treated as a custom measure, so capacity limits also impact how savings are calculated.
3. Given the differences in climate across the Forum region, it is appropriate for specific states or utilities to continue to develop localized assumptions for heating hours due to local characteristics of climate, demographics, and behavior.
4. Different types of commercial buildings may also have different operating patterns, and thus different heating hours. When shown to be relevant, savings parameters by location, vintage, or other dimensions should be employed.

[redacted]

This category is limited to commercial natural gas boilers and furnaces. Accordingly, the research did not include other types of space heating equipment, such as individual or room space heaters, electric or oil space heating equipment, or associated controls such as boiler reset controls.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, unit capacity, baseline and installed efficiency, and full load heating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	Billing analysis (Option C) supported by telephone surveys and/or on-site inspections. Telephone surveys can be used to confirm installation and gather data on facility size and operating hours to support the billing analysis.	Billing analysis is only valid when the pre-existing (electric bills from the pre-retrofit period) is the appropriate baseline to be used in impact analysis.
Alternative M&V Methods	Adding on-site inspections to the basic method above improves confidence in building characteristics and supports collection of equipment nameplate data. Basic short-term measurements (Option A) can be added on electrical support equipment such as furnace fans and boiler pumps to refine savings estimates.	Metering methods would include time-of-use CT loggers and spot power measurements.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is probably excessive for stand-alone gas heating equipment but would be appropriate for evaluating significant measures or those in a comprehensive package.	Natural gas sub-meters can be installed to isolate the heating equipment from other end uses.

1.2.8 C&I HVAC: Prescriptive Chillers

Prevailing Algorithm for Energy and Demand:

kWh savings = Tons x Δefficiency x Annual operating hours
kW savings = Tons x Δefficiency x Demand factors

Notes on Algorithm:

1. "Δefficiency" (kW/ton) refers to the difference in efficiency between the baseline and installed equipment, i.e. ($\text{Efficiency}_{\text{baseline}}$ - $\text{Efficiency}_{\text{installed}}$).
2. "Annual operating hours" are either equivalent full load hours (EFLH) or cooling load hours (CLH).
3. The demand savings algorithm excludes operating hours and incorporates demand factors. These multipliers are called coincidence factors or load factors that modify the chillers peak kW consumption.
4. Prescriptive chiller savings algorithms neglect the impacts of support systems such as pumps, controls, and tower fans.

Description of Inputs:

Baseline Efficiency: Rated efficiency of baseline equipment as per energy code, established standards, or baseline study. Often in units of Energy Efficiency Ratio (EER) for air cooled chillers, kW/ton for water cooled chillers, or the dimensionless coefficient of performance (COP). Depending upon the application, an integrated part load value (IPLV) may be a more appropriate efficiency, particularly for annual energy savings. Baseline efficiencies vary greatly by type (air-cooled/water-cooled, reciprocating/screw/centrifugal) and size and should be supported by technical baseline studies.

Installed Efficiency: Rated efficiency of installed equipment as per manufacturer's performance data.

Full Load Cooling Hours: The ratio of annual cooling unit energy to nameplate peak demand, as informed by technical metering studies designed to update hours-of-use assumptions. Regional Technical Reference Manuals (TRMs) employ estimates ranging from 497 to 3653 full load hours, depending upon region and building type.

Demand Factors: Adjustments to rated demand for use in deriving coincident impacts; recommendation is to consolidate these discrete adjustments into combined Summer and Winter coincidence factors.

Loading: The ratio of peak observed to rated maximum load for a piece of equipment. A discrete factor to express equipment over sizing effects at the typical unit level.

Diversity: The ratio of the maximum combined demand to the sum of non-coincident demands across a group. A discrete factor which expresses the extent to which a group contributes to a combined maximum.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 67% to 100% across the regional TRMs. Coincidence must reflect localized climate conditions and should be based upon technical research studies.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors range from 0% to 67% across the regional TRMs.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Load factors are included in some calculations to account for average seasonal loading and/or oversized systems. By standardizing on Equivalent Full Load Hours, a load factor term is no longer needed.
2. Consolidate load, diversity, and coincidence factors into single factor combining all peak coincidence drivers.
3. Standardize Efficiency. kW/ton is most commonly used to estimate savings, but Integrated Part Load Value (IPLV) can be a better representation of seasonal performance under varying loads.
4. Facility type is unspecified across most TRMs but default operating hours rely on average operation of multiple facility types across regions. Identifying annual operating hours by selected facility types will provide more accurate estimation of prescriptive savings by capturing the unique operating profiles for each facility.

This category is limited to air-cooled and water-cooled chiller installations in commercial and industrial facilities as a prescriptive measure. Custom chiller installations are covered under C&I Custom Measures.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, chiller capacity, baseline and installed efficiency, and full load cooling hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering can offer the most cost-effective approach to prescriptive chiller projects.	Metering methods include interval amp/kW recording or time-of-use loggers coupled with spot power measurements.
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with metering that fully captures the entire chiller water system including supporting pumps and tower fans (Option B). Engineers can analyze hourly energy consumption for baseline and installation conditions in a dynamic spreadsheet model using Typical Meteorological Year (TMY) data.	Additional parameters of value include supply and return water temperature and water flow in gallons/minute.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at capturing measure interaction. Simulation modeling is particularly good at temperature dependent equipment, but requires a wealth of building and operational characteristics for an accurate model.	Metering would mirror Option B probably with whole premise interval kW and some space temperatures.

1.2.9 C&I HVAC: Unitary/Split

Prevailing Algorithm for Energy and Demand:

Cooling Calculations:

kWh Saved = (Size in kBtu/hr) x ($1/\text{Efficiency}_{\text{baseline}} - 1/\text{Efficiency}_{\text{installed}}$) x (Full Load Cooling Hours) / 1,000

Heating Calculations:

kWh Saved = (Size in kBtu/hr) x ($1/\text{Efficiency}_{\text{baseline}} - 1/\text{Efficiency}_{\text{installed}}$) x (Full Load Heating Hours) / 1,000

Demand Calculations:

kW Saved = (Size in kBtu/hr) x ($1/\text{Efficiency}_{\text{baseline}} - 1/\text{Efficiency}_{\text{installed}}$) x (Coincidence Factor) / 1,000

Notes on Algorithm:

1. Seasonal Energy Efficiency Ratio (SEER) is used to calculate cooling energy savings for air source heat pumps and AC units that are < 65,000 Btu/hr in size.
2. Energy Efficiency Ratio (EER) is used to calculate cooling energy savings for all water source heat pumps and for air source heat pumps and AC units that are < 65,000 Btu/hr in size. EER is also used for cooling demand savings.
3. Heating Seasonal Performance Factor (HSPF) is used to calculate heating savings for air source heat pumps < 65,000 Btu/hr.
4. COP (Coefficient of Performance) is used to calculate heating savings for units that are < 65,000 Btu/hr in size. COP is also used for heating demand savings.
5. Equivalent Full Load Hours (EFLH) is used to annualize savings. Separate operating hours are required for heating and cooling modes.

Description of Inputs:

Baseline Efficiency: Rated efficiency of baseline equipment as per energy code, established standards, or baseline study. Units vary as outlined above. Baseline efficiencies vary greatly by type (air conditioner/heat pump, air-source/water-source) and unit capacity and should be supported by technical baseline studies.

Installed Efficiency: Rated efficiency of installed equipment as per the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) database or manufacturer data.

Full Load Cooling/Heating Hours: The ratio of annual cooling/heating unit energy to nameplate peak demand, as informed by technical metering studies designed to update hours-of-use assumptions. Regional Technical Reference Manuals (TRMs) employ widely varying estimates depending upon cooling/heating mode, region, and building type.

Demand Factors: Adjustments to rated demand for use in deriving coincident impacts; recommendation is to consolidate these discrete adjustments into combined Summer and Winter coincidence factors.

Loading: The ratio of peak observed to rated maximum load for a piece of equipment. A discrete factor to express equipment over sizing effects at the typical unit level.

Diversity: The ratio of the maximum combined demand to the sum of non-coincident demands across a group. A discrete factor which expresses the extent to which a group contributes to a combined maximum.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 44% to 100% across the regional TRMs. Coincidence must reflect localized climate conditions and should be based upon technical research studies.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Regional estimates tend to assume 100% for heating mode, but this warrants improvement via further research.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Operating hours is the most dynamic savings input variable, and a consistent method should embrace inputs that reflect operational diversity by location, building type, or vintage. A consistent regional approach can still reflect regional and operational differences: New York should continue using Equivalent

[redacted]

Full Load Hours lookup tables by city, but Rhode Island need not.

2. Electric resistance operation is not included in savings estimates, but these savings should be included when water source heat pumps replace air-to-air systems.
3. Standardize Cooling Capacity Units on Btu/hr. Using capacity estimates in kBtu/hr instead of tons prevents rounding errors by excluding nominal designations (10 tons) that may cover several different units.
4. Eliminate Loading/Sizing Factor. Load factors are included in some calculations to account for over sizing systems in the field, but this can be addressed in the Equivalent Full Load Hours parameter.
5. Given the differences in climate across the Forum region, it is appropriate for specific states or utilities to continue to develop localized assumptions for cooling and heating hours due to local characteristics of climate, demographics, and behavior.

[redacted]

This category is limited to unitary HVAC installations in commercial and industrial facilities as a prescriptive measure. Unitary equipment covers split system AC, packaged systems, air-source heat pumps, and water source heat pumps. Custom unitary air conditioning applications are covered under C&I Custom Measures.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, HVAC unit capacity, baseline and installed efficiency, and full load cooling *and heating* hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering can offer the most cost-effective approach to prescriptive chiller projects.	Metering methods include interval amp/kW recording or time-of-use loggers coupled with spot power measurements.
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with metering that fully surrounds the measurement boundary (Option B). Engineers can analyze hourly energy consumption for baseline and installation conditions in a dynamic spreadsheet model using Typical Meteorological Year (TMY) data.	Interval kW metering on whole package units or both indoor/outdoor components of a split system.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at capturing measure interaction. Simulation modeling is particularly good at temperature dependent equipment, but requires a wealth of building and operational characteristics for an accurate model. May be a viable option for buildings with many HVAC units, zones, or solar coupling effects.	Metering would mirror Option B probably with whole premise interval kW and some space temperatures.

1.2.10 C&I HVAC: Other Measures

Prevailing Algorithm for Energy and Demand:

kWh savings = (Size in Tons) x (Energy Savings Factor)
kW savings = (Size in Tons) x (Demand Savings Factor)

Notes on Algorithm:

1. The prevailing savings approach for all three measures - economizers, dual enthalpy controls, and programmable thermostats - is to employ "savings factors" which scale by HVAC unit size.

Description of Inputs:

Unit Size: HVAC unit capacity in tons of cooling. Nominal value from equipment nameplate.
Energy Savings Factor: Derived from an impact study. Estimates in Forum region Technical Reference Manuals (TRMs) vary greatly from 25 to 289 kWh/ton for dual enthalpy controls.
Demand Savings Factor: Most TRMs do not take credit for kW impacts. One TRM uses 0.289 kW/ton for dual enthalpy controls.
Summer Coincidence: Most TRMs do not take credit for kW impacts. One TRM uses 40% for summer coincidence. Recommend technical research to support savings factors and improve coincidence estimates.
Winter Coincidence: Most TRMs do not take credit for kW impacts. One TRM uses 0% for winter coincidence. Recommend technical research to support savings factors and improve coincidence estimates.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. The lack of reliable source documentation makes it difficult to compare savings assumptions and state what variables are the most accurate and reliable. Given the lack of uniformity between the models, assumptions, and savings factors, more measurement-based research (and perhaps simulation modeling) is warranted to improve consensus and confidence of HVAC economizer and control savings across the Forum region.

[redacted]

The Forum subcommittee for this project elected to limit this Other HVAC category to HVAC control measures such as thermostats, economizers, and dual-enthalpy controls. This category is limited to prescriptive installations in commercial and industrial facilities. Custom HVAC applications are covered under C&I Custom Measures.

Aspect	Detailed Approach	Comments
Program Tracking	<u>At a minimum</u>: initial gross energy and demand savings, as well as initial net impacts as applicable. <u>Additional</u>: number of installed units, unit capacity and efficiency, full load cooling hours, free cooling/setback hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with limited measurements on a sample of program participants (Option A). Site visits for HVAC control measures often focus upon accurately inspecting and verifying operation of the controls.	Metering methods may include strategically placed time-of-use loggers to verify controls.
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with metering that fully captures the impacts of the control (Option B). An hourly impact analysis would isolate the control impacts from the monitored data stream and assess across a Typical Meteorological Year (TMY) dataset.	Metering would be interval kW measurements on the affected HVAC units. Advanced metering can include enthalpy readings and damper position.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at measure interaction but also control schema. Simulation modeling requires a wealth of building and operational characteristics for an accurate model. May be a viable option for buildings with many HVAC units and complex controls.	Metering would mirror Option B probably with whole premise interval kW and some space temperatures.

1.2.11 C&I Lighting (New Construction)

Prevailing Algorithm for Energy and Demand:

kWh Saved = $(\text{Quantity}_{\text{baseline}} \times \text{Watts}_{\text{baseline}}) - (\text{Quantity}_{\text{installed}} \times \text{Watts}_{\text{installed}})$ / 1000 × (Annual Hours)

kW Saved = $(\text{Quantity}_{\text{baseline}} \times \text{Watts}_{\text{baseline}}) - (\text{Quantity}_{\text{installed}} \times \text{Watts}_{\text{installed}})$ / 1000 x (Coincidence Factor)

Notes on Algorithm:

1. Some Technical Reference Manuals (TRMs) stipulate the wattage reduction, utilizing a common Quantity term and substituting a □Watts or kW/unit term for $(\text{Watts}_{\text{baseline}} - \text{Watts}_{\text{installed}})$ in the equation above.
2. While some algorithms employ an in-service rate (ISR), it is less prevalent in the C&I sector than for residential; many C&I programs either exclude ISR or assume it to be 100%.

Description of Inputs:

Baseline Fixture Quantity: The number of fixtures in the corresponding baseline. The same as **Installed Fixture Quantity** for one-to-one replacements.

Baseline Fixture Wattage: Connected wattage of the baseline fixture. For C&I new construction, usually obtained from lookup tables or derived from lighting power density tables in American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1.

Installed Fixture Quantity: The number of installed fixtures.

Installed Fixture Wattage: The rated wattage of the installed fixture, inclusive of both lamp and ballast. Obtained from nameplate data.

Annual Hours: The number of operating hours for the fixture in a typical year. For C&I lighting, either site-specific or assigned by building type. Lighting hours-of-use studies by building type inform program estimates when site-specific hours are not available.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 35% to 100% across the regional TRMs.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors range from 36% to 100% across the regional TRMs.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. A calculated savings methodology would facilitate regional consistency better than stipulated savings. Demand reductions by lighting technology are logical stipulations as inputs, and a consistent algorithm would allow for localized tuning of hours and coincidence for savings impacts.
2. Two distinct approaches are used in the region: lookups by building type and site-specific hours. A blended approach appears to be a logical and reasonable compromise between these two extremes. Site-specific lighting hours could be employed when available, but prescriptive lighting hours would default to lookup tables by building type or other relevant dimension.
3. In-Service Rate is a valid effect; the only question remains whether to account for it in preliminary or evaluated savings. Recommend dropping the ISR from the C&I lighting algorithm and capturing its effect in the gross evaluated realization rate.
4. There is an opportunity for the region to standardize on an interactive effects approach for C&I lighting. This can be an engineering-based interactive methodology or simply agreeing to include localized HVAC interaction factors in the standard C&I lighting algorithm.
5. Given demographic, geographic, program maturity, and behavioral differences in lighting usage across the Forum region, localized assumptions are prudent for lighting hours, peak coincidence, and HVAC interaction.

This category encompasses commercial and industrial lighting in new construction programs.

Aspect	Detailed Approach	Comments
Program Tracking	<u>At a minimum</u>: initial gross energy and demand savings, as well as initial net impacts as applicable. <u>Additional</u>: installed quantity and wattage, corresponding baseline, fixture location, annual operating hours, in-service rate, HVAC interaction factor.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. Fixture location is critical for evaluation.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Complete inspection and count of all installed lighting with spot verification of lamp/ballast type. Characterize cooling/heating zones and equipment for assessment of HVAC interactive effects. Analysis with simple engineering models.	Time-of-use lighting loggers on a broad sample of fixtures, typically stratified by savings, room type, and or operating schedule.
Alternative M&V Methods	Some C&I lighting installations warrant very high, in-building sample rates or advanced interval metering (Option B). Examples include private office spaces with high uncertainty/diversity, hotel rooms/dormitories, and lighting systems with extensive controls. Interval kW meters have proven useful for recording load on lighting circuits with many, individual occupancy sensors or dimming controls. Analysis with simple engineering models or 8,760 spreadsheets for rigorous assessment of coincident impacts.	More liberal use of lighting loggers. Or: many commercial buildings isolate lighting systems in 277V power panels which can offer a prime opportunity for interval metering on large amounts of lighting.

1.2.12 C&I Lighting (Retrofit)

Prevailing Algorithm for Energy and Demand:

$\text{kWh Saved} = (\text{Quantity}_{\text{baseline}} \times \text{Watts}_{\text{baseline}}) - (\text{Quantity}_{\text{installed}} \times \text{Watts}_{\text{installed}}) \,/\, 1000 \times (\text{Annual Hours})$

$\text{kW Saved} = (\text{Quantity}_{\text{baseline}} \times \text{Watts}_{\text{baseline}}) - (\text{Quantity}_{\text{installed}} \times \text{Watts}_{\text{installed}}) \,/\, 1000 \times (\text{Coincidence Factor})$

Notes on Algorithm:

1. Some Technical Reference Manuals (TRMs) stipulate the wattage reduction, utilizing a common Quantity term and substituting a □Watts or kW/unit term for ($\text{Watts}_{\text{baseline}} - \text{Watts}_{\text{installed}}$) in the equation above.
2. While some algorithms employ an in-service rate (ISR), it is less prevalent in the C&I sector than for residential; most programs either exclude ISR or assume it to be 100%.

Description of Inputs:

Baseline Fixture Quantity: The number of pre-existing fixtures.
Baseline Fixture Wattage: Connected wattage of the pre-existing fixture for C&I retrofit.
Installed Fixture Quantity: The number of installed fixtures.
Installed Fixture Wattage: The rated wattage of the installed fixture, inclusive of both lamp and ballast. Obtained from nameplate data. Rarely measured independently.
Annual Hours: The number of operating hours for the fixture in a typical year. For C&I lighting, either site-specific or assigned by building type. Lighting hours-of-use studies by building type inform program estimates when site-specific hours are not available.
Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 17% to 100% across the regional TRMs.
Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors range from 36% to 100% across the regional TRMs.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. A calculated savings methodology would facilitate regional consistency better than stipulated savings. Demand reductions by lighting technology are logical stipulations as inputs, and a consistent algorithm would allow for localized tuning of hours and coincidence for savings impacts.
2. Two distinct approaches are used in the region: lookups by building type and site-specific hours. A blended approach appears to be a logical and reasonable compromise between these two extremes. Site-specific lighting hours could be employed when available, but prescriptive lighting hours would default to lookup tables by building type or other relevant dimension.
3. In-Service Rate is a valid effect; the only question remains whether to account for it in preliminary or evaluated savings. Recommend dropping the ISR from the C&I lighting algorithm and capturing its effect in the gross evaluated realization rate.
4. There is an opportunity for the region to standardize on an interactive effects approach for C&I lighting. This can be an engineering-based interactive methodology or simply agreeing to include localized HVAC interaction factors in the standard C&I lighting algorithm.
5. Given demographic, geographic, program maturity, and behavioral differences in lighting usage across the Forum region, localized assumptions are prudent for lighting hours, peak coincidence, and HVAC interaction.

This category encompasses commercial and industrial lighting in retrofit programs.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: installed quantity and wattage, corresponding baseline, fixture location, annual operating hours, in-service rate, HVAC interaction factor.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. Fixture location is critical for evaluation.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Complete inspection and count of all installed lighting with spot verification of lamp/ballast type. Characterize cooling/heating zones and equipment for assessment of HVAC interactive effects. Analysis with simple engineering models.	Time-of-use lighting loggers on a broad sample of fixtures, typically stratified by savings, room type, and or operating schedule.
Alternative M&V Methods	Some C&I lighting installations warrant very high, in-building sample rates or advanced interval metering (Option B). Examples include private office spaces with high uncertainty/diversity, hotel rooms/dormitories, and lighting systems with extensive controls. Interval kW meters have proven useful for recording load on lighting circuits with many, individual occupancy sensors or dimming controls. Analysis with simple engineering models or 8,760 spreadsheets for rigorous assessment of coincident impacts.	More liberal use of lighting loggers. Or: many commercial buildings isolate lighting systems in 277V power panels which can offer a prime opportunity for interval metering on large amounts of lighting.

1.2.13 C&I Motors

Prevailing Algorithm for Energy and Demand:

kWh savings = HP x 0.746 x (1/Efficiency$_{baseline}$ - 1/Efficiency$_{installed}$) x (loading) x (annual hours) / 1,000

kW savings = HP x 0.746 x (1/Efficiency$_{baseline}$ - 1/Efficiency$_{installed}$) x (loading) x (demand factors) / 1,000

Notes on Algorithm:

1. Standard motor algorithm; highly consistent in Forum region.

Description of Inputs:

Baseline Efficiency: Rated efficiency of baseline motor as per EPACT 1992. Lookup tables by motor horsepower (HP), type (open drip proof, totally enclosed fan cooled), and speed (rpm).

Installed Efficiency: National Electrical Manufacturers Association (NEMA) efficiency of installed motor as per nameplate data.

Loading: The average percent motor loading. While often ball-parked at 70-80%, best informed by spot power measurement of motor under typical loading conditions.

Annual Hours: The number of hours per year that the motor operates. While some prescriptive motor programs provide for site-specific estimates of operating hours, most Technical Reference Manuals (TRMs) provide default lookup hours by 12-60 facility types and 3-4 end uses.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors vary widely for prescriptive motors across the Forum region.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors vary widely for prescriptive motors across the Forum region.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Stay on Track. The efficient motor measure is already close to a regional standard. The availability and uniformity of base and installed motor data has been widely adopted making only minor adjustments necessary to create a regional measure.
2. Some TRMs prescribe motor operating hours for an extensive list of facility types and applications, while others are more limited. Shared research and operating hour assumptions may help expand efficiency offerings for programs that do not offer non-HVAC prescriptive motors.
3. Do not neglect loading factor; use site-specific when available. The loading factor accounts for motor over sizing and prevents the assumption that all motors operate continuously at full load.

This category is limited to the installation of premium efficient motors in commercial and industrial facilities as a prescriptive measure. Motors installed in conjunction with other measures such as with variable speed drives are not included in this document.

Aspect	Detailed Approach	Comments
Program Tracking	<u>At a minimum</u>: initial gross energy and demand savings, as well as initial net impacts as applicable. <u>Additional</u>: number of installed units, motor horsepower, end use and application (e.g. HVAC supply fan), location, baseline and installed efficiency, loading factor, and annual operating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. Motor location is critical for evaluation.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Basic site visits with time-of-use metering offers the most defensible and cost-effective approach to constant-speed, prescriptive motors.	Metering methods include time-of-use CT or "magnetic field" loggers and spot power measurements.
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with interval kW metering that tracks the electrical performance of the motor throughout its load range (Option B). This added rigor captures part-load efficiency effects that tend to be neglected in a time of use (TOU) metered approach with simple engineering models.	Metering would be interval kW measurements for a reasonable duration to span a variety of motor loading situations.

1.2.14 C&I Variable Speed Drives

Prevailing Algorithm for Energy and Demand:

kWh Saved = Motor horsepower (HP) x energy savings factor (ESF) x annual operating hours
kW Saved = Motor horsepower x demand savings factor (DSF)

Notes on Algorithm:

1. All variable speed drive algorithms in the Forum region boil down to a "savings factor" method, however most programs differentiate factors by building type, equipment type, and/or fan/pump type.
2. The most complex prescriptive variable speed drive (VSD) method utilizes an eleven-bin analysis based on percentage of flow. This adds greater resolution to the calculations, but the underlying algorithm remains consistent.

Description of Inputs:

Motor Horsepower: Motor size in nominal horsepower. From nameplate.
Energy Savings Factor: Estimated from impact studies or theoretical engineering models. Estimates range from 745-1,746 kWh/hp.
Demand Savings Factor: Estimated from impact studies or theoretical engineering models. Estimates range from 0.098-0.744 kW/hp.
Annual Hours: Estimated from impact studies or theoretical engineering models. Estimates range from 1,119-8,670 hours/year.
Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors vary from 0-100% for prescriptive VSDs depending upon the building type and drive application.
Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors vary from 0-100% for prescriptive VSDs depending upon the building type and drive application.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. If methodological consistency is a regional objective, a line may need to be drawn between prescriptive and custom VSDs, likely with a simpler line-item calculations and savings factors for prescriptive approach.
2. To improve portability of the VSD method, develop standardized kW/hp factor(s) and localized assumptions for operating hours and peak coincidence. Some algorithms provide a range of default operating hours while others embed annual operation in the "ESF" savings factor.
3. The region would benefit from some standardization, for Technical Reference Manuals (TRMs) vary widely in the range of equipment and size (motor horsepower) covered by the prescriptive variable speed drive application. Eleven types of equipment are covered in one TRM while another list only two applicable types. Installations outside the "standard" offerings simply would become a Custom measure.
4. Similarly, a common set of facility types would facilitate regional methodological consistency. The number of discrete facility types ranges from two to sixty amongst TRMs reviewed.
5. Any compliance or exclusion criteria should be clearly documented. The TRMs clearly identify motor size and application but do not always document exclusion criteria.

This category is limited to variable speed drives (VSD) installations in commercial and industrial facilities as a prescriptive measure. Custom VSD applications are covered under C&I Custom Measures.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, motor horsepower, end use and application (e.g. HVAC supply fan), location, savings factors, and annual operating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. VSD location is critical for evaluation.
Recommended M&V Method	On-site inspections with interval kW metering that tracks the electrical performance of the motor/VSD combination throughout its load range (Option B). Lesser rigor would not capture the variability intrinsic to a VSD application.	Metering would be interval kW measurements for a reasonable duration to span a variety of loading situations.
Alternative M&V Methods	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at measure interaction but also control schema. Simulation modeling requires a wealth of building and operational characteristics for an accurate model. May be a viable option for facilities with many VSDs on HVAC systems units.	Metering would mirror Option B perhaps with whole premise interval kW and some space temperatures.

ENERGY STAR Homes Northwest Program

Market Progress Evaluation Report #3

PREPARED BY
ECONorthwest

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ENERGY STAR Homes Northwest Program

Third Market Progress Evaluation Report

A Report to the
Northwest Energy
Efficiency Alliance

December 4, 2006

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EXECUTIVE SUMMARY

ENERGY STAR Homes Northwest promotes the construction and sale of new homes built to the ENERGY STAR Homes Northwest specification, which was designed specifically for the states of Washington, Oregon, Idaho, and Montana. Homes built to this specification are at least 15 percent more energy efficient than Washington and Oregon State energy codes. These ENERGY STAR homes also include high efficiency lighting, windows, appliances, water heaters, insulation, and heating and cooling equipment. As a result, it is estimated that these homes save an average of 1,000 to 1,500 kWh per year for gas-heated homes and 3,700 kWh annually for electrically heated homes.

This third Market Progress Evaluation Report (MPER) presents the findings of a process evaluation based on interviews with the various market actors and agencies involved with the program, including builders, contractors, and state energy offices. The report also includes current data on the new home market in the Northwest as well as an update on progress towards program goals. Finally, a short post-occupancy phone survey was fielded in which recent ENERGY STAR homeowners were asked about their new home.

Progress Toward Goals

The current program goal is to achieve a 14 percent market share for ENERGY STAR homes within the region's new home market by the end of 2009. This goal has been reduced from a 20 percent market share since the last MPER. The goal was reduced as it has taken the program longer than anticipated to establish the ENERGY STAR infrastructure within the housing market.

Within the program territory, there were 87,878 new single-family homes constructed in 2005, an increase of 17 percent over the prior year. Of these, Washington makes up almost half of the total new home construction activity. Initial data through August of 2006 suggests a 10 percent decrease in new home construction activity and this reduction has been incorporated into the ENERGY STAR Homes program goals set for 2006.

As of September 2006, the program was at 79 percent of its overall homes goal for 2006 assuming that all the initiated homes are completed by the end of the year. The shortfall is primarily in Washington, where only 52 percent of the goal for new homes had been met as of September. One possible reason for this shortfall is turnover among the Building Operator Specialist (BOS) positions within Washington. It also appears that it is taking longer than expected for newly recruited builders to begin constructing ENERGY STAR homes.

Process Evaluation Findings

As of September 2006, 567 builders had been recruited to the program, including 219 in 2006 alone. Of all participating builders, 32 were large builders (building more than 100 homes a year) that accounted for 52 percent of the ENERGY STAR homes certified to date. However, small builders (building 4 homes or less annually) account for 80 percent of all builders in the program territory. While large builders are important (especially in the short-term for meeting annual home targets), the program will need to develop strategies to reach and support small builders in order to meet its longer-term market share goals.

Active participating builders are generally satisfied with the ENERGY STAR Homes Northwest program and have been pleased with the services that verifiers and BOSs have provided to them, including technical assistance and training for contractors. The majority of builders are also pleased with the marketing support provided by the program. They said that they take advantage of the marketing materials that the program provides and believe they are important tools for explaining the benefits of ENERGY STAR homes to homebuyers. While participating builders did not consider the building specifications problematic, several were not aware that dedicated CFL fixtures could be used to meet the lighting requirement.

Performance testing contractors report that the ENERGY STAR home requirements have been clear and that project implementation process has been generally smooth. Several did suggest that duct tests should be conducted toward the end of the construction process because several duct test failures resulted from post-installation damage from other contractors. Although performance testers believe the training provided by the program is useful, there was general consensus that it is not sufficient to prepare someone for the field without some sort of hands-on apprenticeship. Most respondents reported having extensive hands-on training before they took the performance testing course, or their company provided continuing training after they completed the course.

State Certification Organizations (SCOs) and Quality Assurance (QA) specialists report that they are spending more time than expected assisting with training verifiers and educating builders on program requirements. Builders in general appear to be pleased with the QA function provided by the program, however. Coordination with the SCOs also appears to be going well in general, although there have been ongoing issues in Idaho where some verifiers feel that they are not receiving equal and fair treatment from the SCO. The evaluation is continuing to monitor this issues and it will be more fully addressed in the next MPER when we will have an expanded sample of market actor and builder in-depth interviews on which to base evaluation conclusions and program recommendations.

In general, it appears that homeowners are very satisfied with the ENERGY STAR homes. While there has been some replacement of lighting (both CFLs and incandescents), the small survey sample sizes make if difficult to draw strong conclusions. The on-site data collection effort planned for late 2006 is designed to provide more definitive data on the retention of lighting measures and these results will be presented in the next MPER.

Market Progress

Based on evaluation findings to date, early indicators of market transformation in the new homes market are apparent. Specific evidence includes reports from builders and HVAC contractors that they have begun to use the ENERGY STAR label to differentiate themselves in the market. In addition, HVAC contractors actively involved in building ENERGY STAR homes have successfully incorporated performance testing standards into their installations and anecdotal reports suggest that both they and some of the builders believe there are benefits associated with the performance testing requirements. Based on the limited number of homebuyer surveys conducted for this report, saving money on their energy bill was cited as the most common reason for purchasing an ENERGY STAR home. The next MPER will include a more comprehensive assessment of market progress as of early 2007, including results from quantitative surveys with builders and homebuyers.

1. INTRODUCTION

1.1 EVALUATION OVERVIEW

This report is the third of four Market Progress Evaluation Reports (MPERs) of the Northwest Energy Efficiency Alliance's (NEEA's) ENERGY STAR Homes Northwest program. This project is one of two major projects within NEEA's Residential Sector Initiative and works in close coordination with NEEA's ENERGY STAR Home Products program – the other project included in the Initiative.

The ENERGY STAR Homes Northwest program promotes the construction and sale of new homes built to the ENERGY STAR Homes Northwest specification, which was designed specifically for the states of Washington, Oregon, Idaho, and Montana. Homes built to this specification are at least 15 percent more energy efficient than Washington and Oregon State energy codes. These ENERGY STAR homes also include high efficiency lighting, windows, appliances, water heaters, insulation, and heating and cooling equipment. As a result, these new homes are designed to save an average of 1,000 to 1,500 kWh per year for gas-heated homes and 3,700 kWh annually for electrically heated homes.

This third evaluation report presents the findings of the process evaluation conducted on NEEA's ENERGY STAR Homes Northwest program. This includes findings from multiple interviews with the market actors and agencies involved with the program, including builders, contractors, and state energy offices. The report also includes current data on the new home market in the Northwest as well as information on progress towards program goals. Finally, a short post-occupancy phone survey was fielded in which recent ENERGY STAR homeowners were asked about their new home. Selected results from these surveys are presented in this MPER.

Table 1 below summarizes the main components of the MPERs planned for the ENERGY STAR Northwest Homes evaluation. Each report will contain a market assessment showing current conditions in the new home market and tracking changes over time. Phone surveys of both builders and new homebuyers were included in the first MPER and will be repeated in the final MPER scheduled for 2007. In-depth interviews with a smaller sample of builders and various market actors, including realtors and building contractors, will be conducted for all four reports. The final two interview rounds will also include several questions related to program processes. The process evaluation component also includes interviews with utilities, state energy offices, and home verifiers involved with program. Beginning in 2005, a combination of the post-occupancy phone survey and on-site audits will be used to collect information on satisfaction and retention of individual measures. A limited impact evaluation for the performance testing component will also be completed and included in the final report. Finally, a review of the cost effectiveness modeling and underlying model assumptions will be conducted for the final evaluation report.

Table 1: Evaluation Report Components

Analysis Component	MPER 1 Baseline Report	MPER 2 (3Q 2005)	MPER 3 (3Q2006)	MPER 4 (1Q 2007)
Market Characterization	λ	λ	λ	λ
Market Actor Interviews	λ	λ	λ	λ
Utility Interviews	λ			λ
Builder Phone Survey	λ			λ
Builder In-Depth Interviews	λ	λ	λ	λ
Homebuyer Phone Survey	λ			λ
Process Evaluation		λ	λ	λ
Post-Occupancy Homebuyer Survey			λ	
Performance Testing Impact Analysis				λ
On-Site Post Occupancy Survey				λ
Review of Cost Effectiveness Modeling		λ		λ

1.2 PROGRAM OVERVIEW

The ENERGY STAR Homes Northwest program officially began in May 2004 with a goal of achieving a 20 percent market share for ENERGY STAR homes within the residential new construction market by the end of 2009. In 2006 the program revised its goal to reflect the longer than anticipated ramp-up time, and now hopes to achieve a 14 percent market share by the end of 2009. The program markets the benefits of building homes to ENERGY STAR standards directly to builders. The ENERGY STAR brand serves as a mechanism to differentiate builders and the homes they build and also provides consumers with an easy way to identify energy efficient homes. Certification, labeling and marketing efforts are designed to increase the market share of ENERGY STAR new homes while simultaneously protecting the ENERGY STAR brand.

While it has been successful in other parts of the country, the national project model for ENERGY STAR homes was not a good fit for the Northwest region. This can be attributed to a number of factors, the most significant of which include the success of robust energy codes in Oregon and Washington, past focus on (electric heat) Super Good Cents branding for new construction, and the lack of an energy-rating infrastructure that has traditionally been used in other parts of the country.

In order to make the ENERGY STAR Homes project work in the Northwest, the EPA worked with NEEA and its stakeholders to develop a tailored specification that includes a package of prescribed conservation measures and is designed to be fuel-neutral. As the current codes in Washington and Oregon already meet the national ENERGY STAR standard, it was necessary to develop new and more stringent ENERGY STAR requirements for the region if significant efficiency gains are to be achieved in the new homes market. (The detailed prescriptive specifications for the various ENERGY STAR Home options are provided in Appendix B.)

In addition to the prescriptive measure requirements, there are several program elements that are designed to assist builders and contractors with the ENERGY STAR requirements. These program elements include:

- Infrastructure development and market actor training and education, particularly for HVAC contractors and performance testers;
- A quality assurance process requiring that:
    - Every central HVAC system be performance tested (unless the State Certification Office (SCO) approves that only a sample of HVAC systems needs to be tested);
    - Every home be inspected by a certified verifier for compliance with ENERGY STAR Northwest project specifications (unless the SCO approves that only a sample of homes needs to be inspected); and
    - Every home be certified by a third-party contractor operating under an independent ENERGY STAR Northwest quality assurance process.
- Marketing, outreach, promotion, and consumer education focused on branding and labeling, quality and value, and other co-branding and cross promotion opportunities. This is done through press releases, articles, and newsletters that advertise the program and provide information on the benefits of ENERGY STAR homes. The program has also developed the program website www.northwestenergystar.com as an additional information resource for builders and potential new homebuyers.
- Coordination and incorporation of multiple project efforts by utilities and others, specifically including technical standards and financial incentives.
- Promotion and support for "plus" packages that increase energy efficiency or other attributes such as green or healthy buildings (beyond base project requirements) that will further support builder differentiation through efficiency.

Future program activities are anticipated to explore and demonstrate emerging new construction products, services and techniques. These efforts may include support for next generation products as well as comprehensive design approaches such as the Zero Energy Home. In addition, NEEA will plan and implement codes and standards activities designed to facilitate code improvements and compliance.

1.3 MARKET PROGRESS INDICATORS

Progress indicators identified at the outset of the program reflect the focus of the project on all facets of the residential new construction market and are designed to address the key market barriers and opportunities discussed above.

Short-term and long-term indicators include:

Short-term Indicators

- Builders use the ENERGY STAR label to differentiate themselves in the marketplace;
- Consumers, builders, and other market actors link ENERGY STAR homes and home quality/value;
- Builders are convinced of the long-term cost savings from reductions in call-backs that should result from performance testing and quality assurance practices;
- Increased awareness by builders and subcontractors of key efficiency and quality issues;
- Other market actors and trade allies are spending their own resources marketing ENERGY STAR Homes and matching NEEA investments;
- Builders and their subcontractors have expanded knowledge and skills necessary to treat key energy efficiency and quality issues, particularly performance testing of HVAC ducts and equipment; and
- Increasing recognition of the ENERGY STAR label and understanding what it means for new homes.

Long-term Indicators

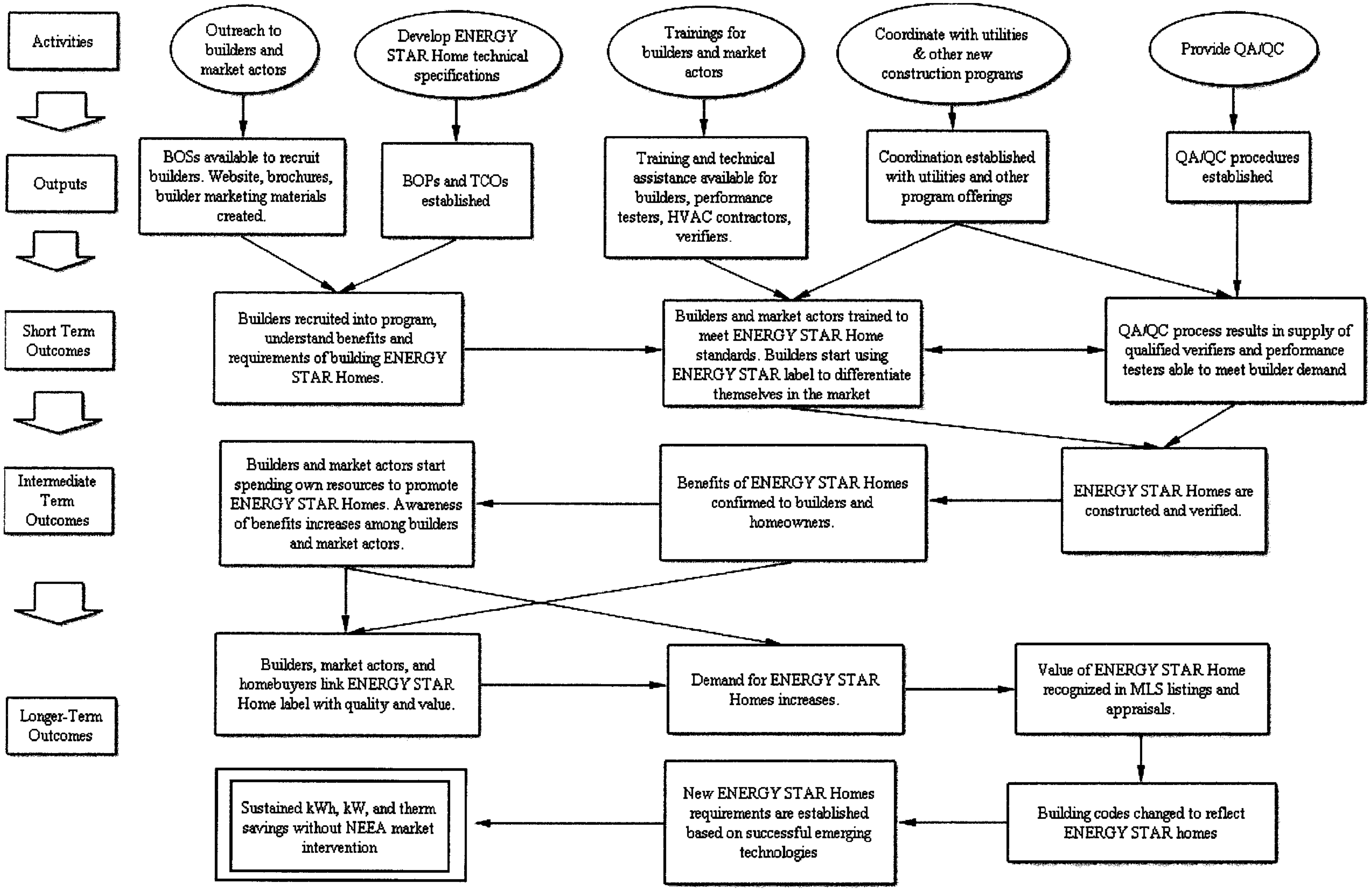
- Multiple Listing Services include whether a home is certified ENERGY STAR in their listings;
- The value of efficiency upgrades is automatically included in the appraisal process;
- Private sector market actors replace NEEA as providers of program services;

- Residential energy codes are upgraded to incorporate some or all of the current ENERGY STAR requirements; and
- A new level of efficiency for ENERGY STAR is adopted based on successful demonstration of new and emerging technologies.

The short and long term indicators reflect the various activity-outcome linkages in the program logic, which is presented in Figure 1. Measurement and tracking of these indicators in the current and future evaluations will provide an indication of the success of the overall program design.

For this MPER, the evaluation focused primarily on process issues relating to program delivery rather than on broader market issues and the progress indicators listed above. As a result, this report does not describe recent progress made by the program on the market progress indicators. Progress on all of the market progress indicators will be researched and included as part of the final evaluation report scheduled for 2007.

Figure 1: ENERGY STAR Homes Northwest Logic Model



2. EVALUATION METHODOLOGY

This evaluation report focuses on the process evaluation of the ENERGY STAR Homes Northwest project. This includes in-depth interviews with all of the major entities that are involved in implementing the ENERGY STAR Homes program. In addition, current market data on new home construction and program progress towards goals is presented to provide context for the process evaluation results. The third major component of this report is a discussion of the results from the post-occupancy survey of ENERGY STAR homeowners.

2.1 MARKET CHARACTERIZATION AND PROGRESS

One of the primary tasks of the evaluation is to characterize the current new home construction market in the region. In particular, the objectives of the market characterization are to:

- Characterize the overall market for new homes in the region and the number of homebuilders so that the potential for the ENERGY STAR homes market can be assessed.
- Show current progress toward program goals, including the number of ENERGY STAR homes certified (and initiated) and the number of builders and verifiers participating in the program.

These tasks were addressed by utilizing secondary data sources such as the building industry publication *Construction Monitor* for information on new homes and the number of homebuilders in the region. Current participation data were taken from the program tracking database maintained by PECI.

2.2 IN-DEPTH INTERVIEWS

The market actor interviews are designed to provide an additional perspective on key ENERGY STAR home components. These interviews were conducted by phone and involved extended conversations with builders, verifiers, and performance testers that are involved in the program.[1] Interviews were also conducted with staff for each state's State Certification Office (SCO) and their Quality Assurance (QA) specialists. All interviews focused on program implementation issues and were designed to elicit suggestions for improving the current program.

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[1] The market actors that were interviewed are defined as follows;

- Builders: A builder who is participating and active in the ENERGY STAR Homes program.
- Verifier: Someone that provides third-party verification that the requirements for an ENERGY STAR home are being met.
- Performance tester: Someone that conducts duct testing and possibly duct blaster and/or a blower door tests.

The sample sizes for each interview group are shown in Table 2. All interviews were conducted by phone during March-June of 2006. Note that some of the people interviewed have more than one role in the program; a verifier may also be a performance tester, for example. In these cases, the respondent was given a separate set of questions addressing each role and is reflected as two separate interviews in the table below.

Table 2: In-Depth Interview Samples

Interview Group	Sample Size
Participating Builders	16
Verifiers	10
Performance Testers	9
SCO / QA Specialists	6
Total	**41**

2.3 POST-OCCUPANCY SURVEY

The final major component of this MPER is a post-occupancy phone survey that was fielded in November 2005 and February 2006. The original intent of this survey was to interview recent ENERGY STAR homebuyers after they had occupied their home for three months. The survey focused on general satisfaction with the home, the importance placed on the ENERGY STAR label during the purchase process, and retention of the lighting measures.

Our initial plan was to get at least 100 completed surveys every three months and to continue fielding the survey throughout the current evaluation. However, our success in getting contact names and phone numbers for these homeowners was less than we expected and we were only able to complete a total of 65 surveys from both survey waves combined. Because of the poor success with this survey and b/c of the desire to verify CFL retention, it will be replaced with an on-site verification task (where the same survey will be administered) as part of the next evaluation report.

3. FINDINGS

3.1 MARKET CHARACTERIZATION

This section provides an overview of the residential construction market for Washington, Oregon, Idaho and Montana as of June 2006 using the most current data available. Builder participation, program goals, and ENERGY STAR home construction data are also presented and provide a context for the interview results presented in the following chapters.

Residential New Construction Market Overview

Table 3 shows the number of new homes built by state since 1998. Single-family home construction activity has been strong throughout the region during recent years and for the entire region, new housing increased by 16.5 percent in 2005 relative to 2004. As of August 2006, new building permits for single family homes is 10 percent less than what was observed for the first 8 months of 2005. This expected slowdown in the region's new home construction market has been taken into account when setting the ENERGY STAR Homes goals for 2006.

Table 3: Single Family New Construction by State (1998-2006)

Year	Washington	Oregon	Idaho	Montana	Total	Change from Prior Year
1998	28,644	16,936	10,277	1,485	57,342	
1999	28,111	16,595	10,497	1,607	56,810	-0.9%
2000	25,471	15,619	9,681	1,565	52,336	-7.9
2001	26,736	16,323	9,738	1,790	54,587	4.3
2002	30,239	17,413	10,845	2,050	60,547	10.9
2003	33,091	17,875	12,601	2,340	65,907	8.9
2004	36,153	20,728	15,106	3,423	75,410	14.4
2005	41,407	23,840	19,172	3,459	87,878	16.5
2006 (Jan – Aug)	25,303	15,090	11,841	2,681	54,915	-10.0

Source: US Census, Housing Units Authorized by Building Permit Report

Table 4 shows the number of builders in regions defined by the Construction Monitor, which provides information on construction activity based on building permits. The data do not cover all of the NEEA program territory but do provide key information about building permits not obtainable from other sources. According to these data, the Inland Empire territory has seen the largest increase in the number of builders over the last two years (26 percent) while Western Montana has seen the largest decrease (10 percent). This is not surprising considering that Washington and Idaho have both seen steady growth in single-family construction while Montana's growth has remained flat for the last two years (see Table 3). On the other hand, while Oregon has also seen steady growth in new single family construction, the Construction Monitor data shows a 4 percent decrease in issued builders permits in the Portland / Vancouver / Salem area.

Table 4: Number of Builders Issued Permits by Region (2004-2006)

Area Name	2004-2005	2005-2006	Percent Change
Inland Empire (Eastern WA, Northern ID)	514	650	26%
Portland / Vancouver / Salem	1,661	1,597	-4
Puget Sound	1,805	1,944	8
Southern Idaho	1,694	1,878	11
Western Montana	1,489	1,343	-10

Source: *Construction Monitor.* Data begin in July and ends in June for the years specified.

Table 5 shows the distribution of builders based on home volume throughout the region. The vast majority of builders (80 percent) are small builders constructing four or less homes a year. In contrast, there are just 67 large builders (constructing 100 homes or more) in the program area, which comprise less than 1 percent of the overall builder population and 34 percent of homes constructed.

Table 5: Builders by Region and Volume (2005-2006)

Region	Number of Units Built (Annually)						
	1-4	5-9	10-24	25-99	> 100	Total	Average
Inland Empire	545	52	31	15	7	650	5.7
Portland-Vancouver	1,218	187	120	53	19	1,597	7.8
Puget Sound	1,466	211	147	94	26	1,944	8.5
Southern Idaho	1,463	207	130	63	15	1,878	7.0
Western Montana	1,038	202	82	21	0	1,343	3.8
Total	5,730	859	510	246	67	7,168	7.1

Source: *Construction Monitor.*

As shown in the preceding tables, most of the new home construction occurs in Washington and Oregon, although there is also significant building activity in Idaho. Areas in Idaho (Inland Empire, Southern Idaho) have also seen the largest recent increases in building activity. Within this market, most builders are small operations that build only a few homes each year. Together this suggests that the program should focus on regions with the most new home building activity and utilize a recruitment strategy that can eventually reach large numbers of small builders.

Progress Assessment

For this MPER, progress on program goals is limited to progress on the builder participation and home construction goals presented in this section. The other market progress indicators discussed in the previous chapter will all be addressed in the final MPER scheduled for 2007.

Table 6 shows the number of new builders who have contractually agreed to participate in the ENERGY STAR Homes Northwest program between January and September of 2006 and also the cumulative number of participating builders since program inception. Results are shown by state and builder volume. Builder recruitment has been active this year, with 39 percent of the total cumulative participating builders in all four states combined having joined the program from January through September 7 of 2006.

Table 6: Participating Builders – New and Cumulative

	2006 Participating Builders (Jan-Sept 2006)		**Cumulative Total of Participating Builders (May 2004 – Sept 2006**		
State	**Small-Volume Builders (<100 homes/year)**	**Large-Volume Builders (100 + homes/year)**	**Small-Volume Builders (<100 homes/year**	**Large-Volume Builders (100 + homes/year)**	**2006 Participating Builders as a Percentage of Cumulative Total**
WA	69	5	136	20	47%
OR	64	0	164	9	37%
ID	68	1	190	3	36%
MT	12	0	45	0	27%
Total	**213**	**6**	**535**	**32**	**39%**

Source: Data provided by PECI as of September 7, 2006

Table 7 shows the distribution of participating ENERGY STAR builders based on how many ENERGY STAR homes they had completed through June 2006. The majority of the builders in each state have yet to complete an ENERGY STAR home. This is in large part due to the large number of builders who joined the program in 2006, and therefore have not had sufficient time to get fully integrated in the program and complete a project. Of the 337 builders who have not yet completed an ENERGY STAR home, 59 percent joined the program in 2006. Aside from the builders that have not yet completed an ENERGY STAR home, the majority of the builders in each state build between 1 to 4 homes per year.

Table 7: Participating Builders by State and Number of Completed ENERGY STAR Homes (May 2004-September 2006)

	Number of Total ENERGY STAR Units Completed						
State	**0**	**1 to 4**	**5 to 9**	**10 to 24**	**25 to 99**	**> 100**	**Total Number of Builders**
ID	106	67	11	6	2	1	193
MT	25	19	1	0	0	0	45
OR	100	59	5	4	4	1	173
WA	106	33	0	10	4	3	156
Grand Total	**337**	**178**	**17**	**20**	**10**	**5**	**567**

Source: Data provided by PECI as of September 7, 2006

Table 8 shows the cumulative number of completed ENERGY STAR homes by builder volume group. This table highlights the importance of getting large builders (builders who build over 100 home per year) to participate. Although only around 6 percent of the total participating builders are large builders (see Table 6), the 5 builders who have completed over 100 ENERGY STAR homes account for 52 percent of the total completed ENERGY STAR homes.

Table 8: Cumulative Number of ES Homes Completed by Builder Volume

Number of ES Homes Completed	Cumulative Completed Homes	Percent of Total
1 to 4	280	11%
5 to 9	100	4%
10 to 24	305	12%
25 to 99	521	21%
>100	1330	52%
Total	**2536**	**100%**

Source: Data provided by PECI as of September 7, 2006

Table 9 shows the construction activity achieved through the ENERGY STAR Homes program as of September 2006. "Certified" homes refer to those that have been constructed and certified as ENERGY STAR-compliant by the program. "Initiated" homes are those that have started construction but are not yet completed, and have their status in the ENERGY STAR Northwest Homes Database listed as "pending."[2]

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[2] Homes outside of the Energy Trust of Oregon territory are not required to be registered in the database before completion, though many are. As a result, the actual number of initiated homes may be larger than what is reported in Table 9.

Although the program goal is listed as a number in the table, it is actually defined as 4.1 percent of the total market in 2006. Actual performance relative to this goal will not be known until final housing numbers are in available for 2006. The goals shown in Table 9 are determined by the program based on the program's own estimates of the housing market for 2006. At the time of this report, the program was predicting a 10 percent decrease in overall housing starts in 2006 relative to 2005.

Rather than have the program estimate housing starts during the current year to determine goals, we recommend that the program consider purchasing housing data (such as F.W. Dodge data) that provides a forecast of new home starts for the upcoming year. This will enable the yearly goals to be determined independently, as the housing starts estimate for the year will be determined through third-party source not affiliated with the program.

Overall, the total number of certified and initiated homes through September 7, 2006 amounts to 79 percent of the program goal for 2006, while certified homes by themselves amount to 47 percent of the program goal for 2006. On a state-by-state basis, Oregon has already met its 2006 goal and Idaho appears to be on target to reach its goal by the end of the year. Montana is currently at 34 percent of its goal, but the goal for that state is a relatively small part of the overall goal for the program.

Washington has the largest share of the overall program goal and as of September only 52 percent of the homes goal had been met for this state. Without a substantial number of new homes initiated and completed by the end of the year, it seems unlikely that the homes goal for Washington will be met. Given the importance of Washington in the overall program goals, it appears that the ENERGY STAR Homes program might not meet its 2006 homes goal. Issues relating to the program and the housing market in Washington will be explored more fully in the next MPER.

It should be noted that not all initiated homes are required to be entered into the program tracking database (except in Oregon), so there may be more program activity than shown in Table 9. There may also be a large increase in activity at the end of year, as there was in December 2005 (see Figure 2). Even when considering these mitigating issues, we still believe that the program should make Washington a priority to help ensure that the overall program goals are met for 2006.

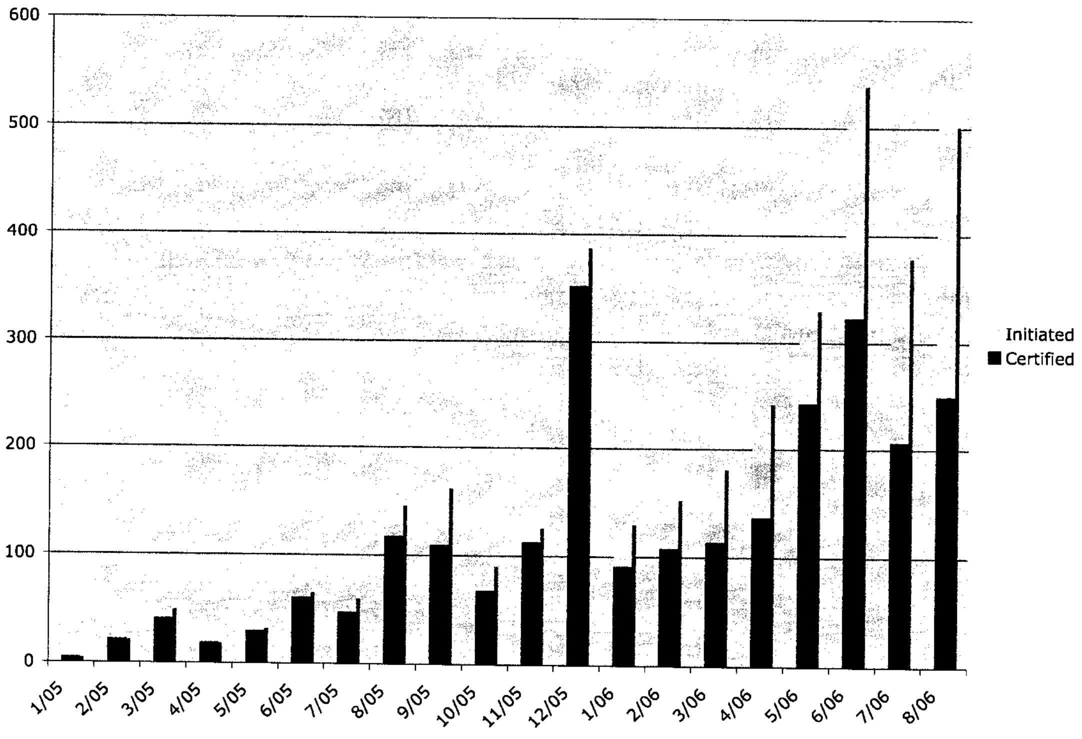
Table 9: 2006 ENERGY STAR Home Construction Status (Jan-Sept 2006)

State	Certified	Initiated	Total Certified and Initiated (Forecast Completions)	NEEA 2006 Goal (Certified Only)	Projected 2006 New Homes	Total Certified and Initiated Homes as a Share of 2006 Goal
WA	480	313	793	1,513	36,894	52%
OR	682	406	1088	871	21,241	125%
ID	325	299	624	700	17,082	89%
MT	23	20	43	126	3,082	34%
Total	**1510**	1038	2,548	**3,210**	**78,299**	79%

Source: Certified and Initiated homes and goal data from PECI as of September 7, 2006. 2006 Projected New Homes estimated by CSG.

Figure 2 shows the monthly totals of homes that have been initiated and certified from January 2005 through August 2006. It is clear that there has been a steady increase in the number of completed ENERGY STAR homes over the period shown. The combined monthly total of initiated and certified homes in 2006 alone has increased by nearly 400 percent since January 2006. Monthly program activity by state is provided in Appendix D.

Figure 2. Certified and Initiated Homes (Monthly Totals)



Source: Data provided by PECI as of September 7, 2006, ECONorthwest

Table 10 shows the number of participating verifiers and performance testers that have joined the program between January and September of 2006. Of the four states, Washington has seen the largest growth of both participating verifiers and performance testers. The cumulative totals since May 2004 for both verifiers and performance testers are also shown in Table 10. The total number of verifiers and performance testers that joined the program in 2006 represent 27 percent and 30 percent of the cumulative total, respectively.

Table 10. 2006 Participating Verifiers and Performance Testers

	Verifiers		Performance Testers	
State	**New Jan – Sept 2006**	**Cumulative May 2004 – Sept 2006**	**New Jan – Sept 2006**	**Cumulative May 2004 – Sept 2006**
WA	19	55	83	125
OR	14	48	36	135
ID	0	13	1	10
MT	3	19	5	20
Total	36	135	86	290

Source: *ENERGY STAR Data Base.* Data as of September 8, 2006.

3.2 BUILDER INTERVIEWS

This section presents the results of in-depth interviews conducted with participating ENERGY STAR Homes builders. The purpose of the builder interviews is to provide the builder perspective on program process issues being addressed by the evaluation. The analysis is generally qualitative in scope, although percentages or numbers of respondents are cited to help the reader understand the relative importance of findings. Note, however, that 1) many of the questions asked were open-ended, and did not necessarily yield clear responses; and 2) the sample was too small to provide meaningful statistical analysis of results.

The participating builders were recruited from the program tracking database maintained by PECI. The recruiting effort emphasized those builders that had the most experience in the program in terms of the number of ENERGY STAR Homes completed. We also attempted to get a mix of active participants that we had interviewed for previous reports as well as new participants that were actively building ENERGY STAR homes according to the program tracking database. A total of 16 in-depth interviews were completed with builders actively participating in the program.

Table 11 shows how the builder interviews were distributed across the states. For the participating builder interviews, we attempted to get a mix of builders (both production and custom) across the entire region.[3] The builder interviews were conducted by phone during March of 2006.

Table 11: Participating Builder Interview Sample By State

Builder Group	WA	OR	ID	MT	Total
Participating Builders	5	5	6	0	16
Total	**5**	**5**	**6**	**0**	**16**

Regarding their home building plans for 2006, the interviewed builders had the following characteristics:

- The number of homes planned for 2006 by interviewed builders ranged from as few as 8 to as many as 1,400.
- The two largest builders interviewed account for about 66 percent (2,400 of 3,615) of the total number of homes the builders said they plan to build in 2006.
- Around 56 percent of the homes planned for 2006 by interviewed builders are expected to be ENERGY STAR rated.
- 11 of the respondents said they planned to build over 50 homes in 2006, 7 of which said they planned to build over 100 homes.
- One of the builders had recently become a participant and had yet to break ground on a planned ENERGY STAR home.[4]

Although fourteen of the 16 builders interviewed said that all or almost all of their 2006 production will be ENERGY STAR qualifying, one of the large builders (more than 1,000 homes) that offers ENERGY STAR as an option said he expects around 3 percent of the homes built to be ENERGY STAR qualifying. One builder said that although all 8 of the houses he expects to build in 2006 will meet ENERGY STAR requirements, none will actually be certified because he is not planning on participating with the program any longer, as discussed in greater detail subsequently. Overall, the interviewed builders expect to build almost 2,050 ENERGY STAR rated homes in 2006. It is important to note that a single large builder accounts for around 45 percent of the projected volume of ENERGY STAR Homes.

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[3] Given the small sample size and the low level of building activity, we did not interview any builders in Montana but will be interviewing them for the final MPER.

[4] This builder had several homes committed as ENERGY STAR and so was selected to be interviewed to get his initial perspectives on the program.

Program Benefits and Advantages

When asked to name the biggest advantages to the builder from participating in the ENERGY STAR homes program, builders offered the following:

- Almost all the participating builders gave responses related to product differentiation, marketing, and the recognition enjoyed by the ENERGY STAR name.
- About one-third of the respondents said that customer demand for ENERGY STAR features and the importance of energy savings were program benefits. Some builders offered comments such as the benefits of having "the ability to fly the [ENERGY STAR] flag and show the people that it is going to save some money," and "as utility energy prices go up customers are looking for greater efficiency."
- Two of the respondents cited the benefits of the 3rd party verification provided through the program as an important benefit.
- Two builders stated that sustainable building was important to them personally and to their employees. Some builders offered comments such as "energy efficiency is important, both personally and to customers."
- One builder located in Idaho stated that he plans on ending his participation with the ENERGY STAR Homes program. This individual stated that he had no problem with the "building integrated" requirements of the ENERGY STAR Homes program, referring to the insulation and duct requirements, but he did not believe that his customers were willing to pay for the added costs of the additional ENERGY STAR components such as lighting and appliances.

When asked if they believed that building to ENERGY STAR requirements reduced callbacks on their homes, five of the builders said that they think it does reduce callbacks. Increased insulation resulting in reduced indoor draft was cited as the most common reason for fewer callbacks, along with fewer HVAC problems. Of the remaining 11 builders, five stated that they did not believe building to ENERGY STAR requirements reduced callbacks and six builders stated that they did not know.

Builders were also asked to name the most and least valuable aspects of assistance offered by the program:

- Nine respondents cited the Building Outreach Specialist (BOS) or their verifier as the most valuable assistance offered by the program, often mentioning the person by name.
- Another one-third of respondents (5) said the marketing materials and assistance were the most useful. Two builders specifically commented on the benefits of the

new computer kiosks that ENERGY STAR is beginning to use to educate customers about the benefits of ENERGY STAR homes.

- Two respondents cited contractor training as the most important assistance that the program provides.

- Very few of the builders were able to identify less valuable aspects of program assistance. In response to this question, one builder stated that the lack of knowledge about ENERGY STAR homes on the part of sales agents and realtors is a problem. Another builder commented on the amount of paperwork required by the program and also cited problems understanding program acronyms.

From the interviews it is clear that the BOSs and verifiers are providing a wide range of important services to the participating builders. Many of the builders commented that their BOS or verifier helped them "get over program hurdles," or "get contractors up to speed."

Twelve of the 16 respondents stated that their local utilities support the ENERGY STAR homes program in some capacity. The majority of the utility support comes in the form of financial incentives for the ENERGY STAR rating or, in some cases, for specific equipment. One utility offered a discount for the temporary hook-up during the building phase. Another builder explained that the city where he works awards building permits based on a point system.

Developments that are ENERGY STAR rated receive extra points, therefore making it easier to receive a building permit. This particular builder said that this was the primary reason that he decided to participate in the ENERGY STAR program. Of the 12 respondents that stated that their utilities provide some support for the program, six indicated that the support was important to them.

The majority of respondents (13) knew of other energy efficiency programs for homes. At least two builders, both in Oregon, were also participating in the Earth Advantage program. When asked what types of assistance the builders would like ENERGY STAR to provide, eight of the builders interviewed said there was no additional assistance they wanted from the ENERGY STAR Homes program, with several offering comments that "they have been pretty helpful" or "everything has been going smooth."

The most frequently requested additional assistance or recommended changes included:

- Additional marketing and education to customers;

- Added financial incentives and rebates;

- Technical support; and

- Best practices meeting or builder chat group.

Program Requirements

General Requirements

Builders were asked about their awareness of the different Builder Option Packages (BOPs) that were available to them for meeting the ENERGY STAR Home requirements. In general, a BOS will suggest a single set of requirements to a builder based on what the BOS believes will best fit that builder's needs. As a consequence, most builders are generally unaware of the full range of the BOP and Technical Compliance Options (TCO's) available to them.[5] This is by design, as the program does not want to unnecessarily overwhelm builders with all available options but instead makes a recommendation as to which option(s) will likely be most useful for each builder.

In response to the questions concerning the value of different compliance options, builders provided the following comments:

- Some builders offered comments such as "the more flexibility the better," "good system," and the BOPs are "easy to use."

- Other builders offered comments such as "the BOPs are not easy to understand," and they are "too rigid." The respondent who stated that the BOPs are too rigid commented that the prescriptive nature of the ENERGY STAR program does not take into account differences in each house. As an example, the builder pointed out that the ENERGY STAR homes program does not distinguish between a house with fewer windows but less wall insulation and a house with more windows but greater wall insulation, even though both houses will be similar in terms of energy efficiency, since windows have much lower insulation properties (higher U-Value) than walls with insulation.

Program Information

- All but two respondents said that it had been easy finding information about the program requirements. Of those that found it easy to get program information, five cited their BOS or verifier as an important source of information.

Other responses on this topic include the following:

- One of the exceptions said that his organization had been building houses to ENERGY STAR specifications before they enrolled in the program and therefore had no need to look into program requirements. The respondent did say that a verifier had been providing assistance to the organization's builders.

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[5] Details on all of the BOPs and TCOs are provided in Appendix B.

- The other exception stated that he had not been enthusiastic about the program to begin with and had not actively looked for any of the program requirements. This builder has not completed any ENERGY STAR rated homes and does not plan on continuing his participation with the ENERGY STAR program.

In response to a question about who has provided the most program support, ten out of the eleven builders who responded stated that their verifier or BOS provided the most assistance. The respondents usually provided the person's name, and it is not clear if they knew whether the person is a verifier or BOS. One builder stated that his heating contractor has provided the most program support.

Air Conditioners

In response to a question regarding how the ENERGY STAR requirement to use SEER 13 rated air conditioners affects them, 13 builders said it has not negatively affected them, while two cited cost as the largest effect. Eight of the respondents stated that they had already been using SEER 13 rated air conditioners, with six of those respondents citing that this is already code in their territory.

Lighting Requirement

When asked if the ENERGY STAR requirement that 50 percent of the lighting fixtures/bulbs be ENERGY STAR rated has been an issue, most builders (11 of 16) did not view the lighting requirement as a problem. Respondents were also asked to rank the difficulty in meeting the lighting requirement relative to the other ENERGY STAR home requirements. One quarter (4 of 16) cited this as a major issue.

Although the majority of the respondents did not believe the lighting requirement was a major problem, they did state that the there were some challenges with the requirement:

- The most common difficulty that builders mentioned had to do with the light quality and appearance of the ENERGY STAR rated lighting. One builder mentioned that he typically tries to place the efficient lighting in places were they will not be easily seen, stating that "lighting is not a big issue, but the lights are ugly so it helps to put them in the right spots" so that they are not very prominent. A different builder stated "lighting has not been a problem, although many of the lights available are not very nice."

- One respondent questioned whether the lighting requirement should be part of the ENERGY STAR home program. The builder stated that lighting should be a decision of the homeowner, and if they don't like the lighting that the builders use they will just replace the bulbs.

- Three builders said that their opinion about the lighting equipment has changed since they began the program. Two of these builders had initially questioned the requirement and expected more resistance from clients than they actually encountered. One builder was worried about the added cost, but found some good deals on ENERGY STAR rated lights.

- Four of the respondents did not know that fixtures could be used to meet the lighting requirement. One of these four was a builder that had yet to build an ENERGY STAR home, however.

For the respondents who stated the lighting requirement was a major issue for them, there was no single theme that they all mentioned. Instead, builders had their own unique concerns with the requirement:

- One builder stated that the lighting requirement is "the worst part of the entire program." According the this builder, the problem with the 50 percent lighting requirement is that if the builder installs a decorative chandelier that contains many standard bulbs, the builder must then install extra lighting sockets just so he can install more CFLs to meet the requirement.

- One of the large builders interviewed stated that it would be too much work to change the 300 different standard blueprints that his organization uses to accommodate for ENERGY STAR fixtures, and therefore they just use CFLs to meet the requirement.

- A different builder stated that that "lighting is a tough sell. Customers don't like the ENERGY STAR light bulbs. They put them in, they take them out. Customers feel they are getting an inferior product."

The majority of the builders (10 of 16) purchased their lighting from a lighting distributor such as Seattle Lighting. The remaining builders either purchased their lighting from a "big box" store or had their electrical contractor do the purchasing. Estimates of the added cost per home due to the lighting requirement varied from $40 to $350, with an average estimate of around $100. One builder believed that purchasing ENERGY STAR rated lights might actually reduce the cost of the home because of the financial incentives that are available.

Barriers

Builders were asked what the biggest challenge has been participating in the ENERGY STAR program and what the toughest requirement has been. Three respondents stated that they have had no problems participating in the program. The remaining respondents provided a variety of responses to these questions, with no single barrier or difficulty standing out:

- Three respondents cited the added cost as the greatest challenge in participating in the program, noting that it has been difficult selling the added value to customers who are concerned with the bottom line. Two of these respondents still said they expect 100 percent of the homes that they build to be ENERGY STAR rated. The third respondent, who is a large builder, said he expects around 3 percent of the homes built by his organization to be ENERGY STAR rated.

- Two respondents cited problems getting qualified subcontractors that can do ENERGY STAR quality work.

- One respondent cited the prescriptive nature of the BOPs as a major barrier. The respondent stated that it has been difficult to get new technologies approved for the ENERGY STAR program.

- Other comments had to do with difficulties with specific requirements such as air conditioners (long payback in the northwest), duct testing and lights.

When asked about difficulties finding equipment to meet the ENERGY STAR requirements, all but two respondents stated that they have had no problems locating equipment. One respondent had some trouble locating a gas fired hot water heater that meets the ENERGY STAR requirement and another commented on the difficulty of finding efficient decorative lighting.

Training, Duct Testing, Verification and Quality Assurance

Training

Almost half of the builders (7 of 16) stated that their contractors have received formal training. For the remainder of the builders, six stated that their contractors have received informal training from the verifiers, BOS or testers, and three respondents either did not know or did not think their contractors have received any training. Those who knew their subcontractors had received training all stated that the training had been beneficial and that the contractors were brought up to speed in a timely manner. Those who stated that their subcontractors received informal training also stated that the assistance was beneficial and that they have had no problems.

Duct Testing

In general, the builders interviewed were happy with the duct-testing element of the ENERGY STAR program. Many said that they believe it is one of the more important inspections that the program performs and results in a better HVAC system for the home:

- One-third of the respondents stated that third party verification was an important benefit of the duct testing by helping to ensure that the installations were done correctly.

- Three respondents cited marketing benefits a major benefit of duct testing. Builders made comments such as “It is a big sales feature when you talk to them about it.”

Although many of the builders had a positive view of duct testing, one-third of the respondents either did not know what the benefits of duct testing were or did not believe there were any.

Six of the builders believe that homebuyers are aware of the benefits of duct testing, while 7 builders stated that they do provide at least some marketing materials promoting the benefits of duct testing.

From the builders' perspective, the main benefit of duct testing to homebuyers is that it is an important part of the overall ENERGY STAR package and is responsible for a large part of the energy savings:

- One builder made the comment that "savings are what is most important to customers, and they respond to duct testing."
- One respondent stated that the third party verification is the most important benefit for the homebuyer.

None of the builders interviewed saw any disadvantages to duct testing, and all but one builder stated that it was worth the cost. In general, the builders seem to be happy with their duct testers. None of the builders have had problems locating a tester or scheduling an appointment. The builders stated that the test usually takes 1-2 hours.

Seven of the builders have had at least one house fail the duct test. Minor duct leakage was the most common reason for failure mentioned by the builders. One builder stated that the leaks usually occur "in the stack where the floor transitions," while another builder stated that leaks usually occur where the ducts connect to the furnace. In all cases they said the problem was corrected quickly and the failed test did not result in any significant delays.

When builders were asked if they had any final comments about duct testing, the only comment was that conducting a duct test on every house seemed redundant. The builder recommended letting the verifier decide whether a house needs a duct test.

Verification

All but one builder stated that they have had houses verified through the ENERGY STAR program. Builders found their verifiers through industry contacts, ENERGY STAR program representatives or Earth Advantage program representatives. Builders reported a variety of experiences with the verification process:

- In general, the builders have been very pleased with verification process. Respondents described the process as "smooth" and "great."
- Builders appreciate the services that their verifiers are providing. Respondents commented on the verifier's ability to provide technical assistance, program

information, assistance with problem solving, and help making sure contractors know and can meet ENERGY STAR requirements.

- Four builders said they had failed at least one stage of the verification process. All four builders said that the failures were due to minor issues such as small duct leaks, and all were corrected quickly and without resulting in significant delays.
- One of the builders who said he failed a test did not think it was worth the time or money to fix the minor problem in order to get the ENERGY STAR rating. The same builder stated that the verification process was a major problem with the program. The builder believes that there are too many verification stages, it is too expensive, and that the verifiers focus on "smaller" aspects of the house and not the "larger" building integrated systems such as the HVAC system and insulation.
- Only two of the builders interviewed stated that they had experienced delays due to the verification process. One of these builders, who is located in Oregon, attributed the delay to a lack of verifiers in the area and therefore had difficulty scheduling an appointment. The other builder stated that the verifiers focused too much on smaller components of the ENERGY STAR program, which can cause costly delays and result in minimal benefits.

Builders were asked how long it takes to get the ENERGY STAR label from the time the verifier approves the house. The most common response was around 3 weeks, although one respondent said it took a few months.

When asked if there are any disadvantages to the verification process, only two builders responded. Both said that the main disadvantage has been delays.

Quality Assurance

Builders were asked whether they have had any interaction with the ENERGY STAR quality assurance process. Of the 16 builders interviewed, 5 said that a quality assurance representative had contacted them, and 4 said that at least one of their homes had been inspected. When asked how the QA process went, the builders gave responses such as "quick and easy" and "no problem."

Marketing

Half (8) of the builders interviewed said they use real estate agents to sell their homes. With the exception of one builder who sells home via word-of-mouth, the remaining seven builders use their own sales agents. Other marketing issues reported by the builders include the following:

- The builders that use their own sales agents were more likely to say that their sales agents were knowledgeable about ENERGY STAR and were effectively selling the benefits of ENERGY STAR homes. Many of the builders with their own sales force stated that their sales agents have received some training about the ENERGY STAR program.

- Approximately half of the builders said that they do not believe that real estate agents are effectively selling the benefits of ENERGY STAR to customers. These builders almost all used real estate agent so sell their homes. Many builders commented that it would be helpful if classes were available to train real estate agents.

- Builders believe that it is the ENERGY STAR label, not any individual component of the ENERGY STAR package, that drives consumers to buy ENERGY STAR rated homes. Lighting was not seen as a factor influencing homebuyers.

- One builder said that the third party verification was important to homebuyers because it adds confidence that the building was constructed soundly.

- Most of the builders said they have found the marketing materials provided by the ENERGY STAR program very helpful. The ENERGY STAR plaque and brochures were frequently commented on as being the most useful. One builder was excited about a new interactive education tool that was going to be installed in his sales office.

When asked what aspects of ENERGY STAR homes they promote to customers, most builders cite increased energy efficiency and reduced utility bills. Two builders said they promote the overall ENERGY STAR package as a "green" and sustainable option. Two builders specifically said that they promote the increased comfort and better air quality of ENERGY STAR homes.

Builders were asked what they consider the biggest marketing challenges for ENERGY STAR homes. Eight of the builders were not sure what the biggest marketing challenges are for ENERGY STAR. The respondents that did have opinions about marketing challenges provided the following responses:

- Four builders thought that lack of customer awareness of ENERGY STAR homes was the largest marketing challenge.

- Three builders stated that the increased price for ENERGY STAR homes presents the biggest marketing challenge.

    - One of these builders did not believe that customers were willing to pay more for a home that is ENERGY STAR rated.

    - One large builder considered the added cost to be the greatest marketing challenge, yet this builder also stated that 90 percent of the new homes built by his organization will be ENERGY STAR rated.

Overall, builders were happy with ENERGY STAR efforts to market the program. When asked what the ENERGY STAR program should do to effectively market the program, builders gave responses such as "nothing, they have done a great job providing materials and assistance." Some builders said they would like to see more customer awareness, and recommended things such as a "marketing blitz" and also promoting the builders themselves as being "responsible builders." One builder recommended targeting real estate agents, appraisers, and building inspectors.

When asked if they had any final comments about the ENERGY STAR homes program, the builders provided the following comments:

- "Overall everything is good. I am 100 percent on-board."
- "The program has been painless, a real workable program. It would be nice if the gas company provided rebates."
- "I view the program as an overall package for environmental responsibility. Individual components are not issues, you just do them."
- "ENERGY STAR needs to focus on major building components and also refine the verification process."
- "It would be good to have more builder input and cooperation on the program. Some decisions were made without input from builders."
- "What's the next step for ENERGY STAR? Is there another level coming?"
- "Having different levels of ENERGY STAR, such as platinum, gold, silver...would be useful, both from a builders point of view and also for marketing."
- "It would be nice if there were a wider range of appliances, including entry level appliances. Only high-end ones exist for ENERGY STAR."

3.3 VERIFIER INTERVIEWS

This section presents the results of interviews conducted with participating ENERGY STAR verifiers. These verifiers are specialists providing third-party verification that the requirements for an ENERGY STAR home are being met. The purpose of these interviews is to provide the verifier perspective on the various ENERGY STAR Homes program components and processes. The interviews also provide the verifiers' perspective on how builders and HVAC contractors perceive the verification process. The analysis is generally qualitative in scope, although percentages or numbers of respondents are cited to help the reader understand the relative importance of findings.

In total, interviews were conducted with 10 individuals who are certified as verifiers for the program. The interview sample was chosen to get a mix of verifiers across states and to include those verifiers that had actually completed some ENERGY STAR home verifications. The experience level of the interviewed verifiers ranged from 2 to 350 ENERGY STAR homes inspected.

Table 12 shows how the verifier interviews were distributed across the states. Among the 10 verifiers, 7 were also certified for performance testing in the program. The 2 verifiers in Idaho were interviewed specifically to elicit comments on their relationship with the State Certifying Organization (Idaho's State Energy Office) and one was also interviewed as a performance tester. Only the findings relating to verification tasks are discussed in this section, however.

Table 12: Verifier Interview Sample By State

Builder Group	WA	OR	ID	MT	Total
Verifiers	3	4	2	1	10
Total	**3**	**4**	**2**	**1**	**10**

Business Environment

Five of the verifiers work at private companies that are competing to provide verification services. In addition to verifying ENERGY STAR Homes, all five also provide other services for their builders. The other types of services they provide include:

- Built Green consultations
- Duct testing
- Insulation installation
- Sales of heat recovery equipment
- Inspection services

In most cases, the verifiers we spoke with recruited builders through the relationships they developed from offering these services themselves. A couple of verifiers recruited builders through cold calls based on observed construction activity. One verifier suggested that it would be nice to have an updated list of builders with activity in the area, and they were working with their BOS to find such a list. One also mentioned that it would be helpful to receive an information packet about the program when they get their building permit.

The amount of business each company derived from ENERGY STAR Home verification services varied greatly. At some places, it was 100 percent of their business while at others, just 5 percent. In general, the prospects for future business were mixed. Two verifiers from rural Washington and one from Montana were concerned that they had not picked up more business in their areas. At the same time, one thought there is a strong business opportunity once they get builders on board, and one believed the market is definitely going to grow.

The rates charged for services varied from $115 to $400 per home, depending on what other services were included and if the home was built in a development that qualified for sampling. Verifiers usually lower their per-home charges for larger projects where multiple homes (i.e. a sample) will be verified instead of all the new homes.

Training

Verifiers were asked to evaluate the training they received to become verifiers and any experience they may have had with the trainings for builders and HVAC contractors.

Half of the verifiers had experience with verifying a home's performance in previous programs. These verifiers generally preferred the building science elements of the training as opposed to the technical requirements. One verifier said the most valuable part was "understanding how components work together and *why* they need to work the way they do. How the systems balance. Verifiers need to have a good understanding to explain the benefits to builders."

First-time verifiers appreciated learning the details of the program and getting practical answers from the experienced verifiers about specific questions. One of these verifiers mentioned that the training should "emphasize where to find information about ENERGY STAR requirements and where updates are posted."

Builder trainings were generally perceived as being valuable. In most cases, the verifiers believe the builders understand the basics pretty well. Most of the verifiers indicated that they themselves end up being the builders' real resource for program information, technical assistance, and other program issues. Regarding the training coordination, one verifier mentioned that it is better if PECI does not get involved because "they do not have the relationship with the builder." One verifier suggested that the builder training should include "a checklist that outlines the ENERGY STAR lighting and heating requirements, for example."

The HVAC contractors are showing an "exponential" improvement in their skills, according to one verifier. Most agreed that the contractors initially tend to have difficulties meeting standards, but that they are able to successfully develop the necessary skills with growing experience. Two of the verifiers mentioned that the HVAC trainings could be extended to a full day if they were combined with other certifications. Otherwise, they need to be respectful of the opportunity cost of contractors attending the trainings, even if they are free. One verifier suggested that they should provide a quick reference guide that just covers the ENERGY STAR requirements for HVAC. They think that the current guidelines are too intermixed with requirements pertaining to other aspects of the house (e.g., the lighting).

Comments on Builder Requirements

Verifiers were asked to evaluate how successful the builders were in meeting the various program requirements. It is fairly rare that persistent difficulties with the requirements will cause a home to be dropped from the program, and only one builder was said to have withdrawn from the program altogether. Most often, all of the initial problems are remedied and the house still receives certification.

The most troublesome requirement in the minds of the verifiers is duct sealing. Six verifiers mentioned that leaky duct systems are a common problem. One specific reason mentioned was that contractors do not bid the project right and end up having more work than they planned. Verifiers also mentioned that duct sealing problems often occur when the builders use an HVAC contractor who is new to the ENERGY STAR Homes program. More specifically, the duct blast tests usually reveal leaks around the heating element.

Four verifiers mentioned lighting as a problem for the builders. The problem typically relates to customer and builder objections to the output and quality of light. One verifier said some builders have stopped installing dedicated fixtures due to persistent dissatisfaction with the lighting.

Insulation was also mentioned several times as a problematic requirement. Verifiers indicated that splitting insulation around wires and fluffing insulation rather than forcing it in were frequent issues. Additionally, installing insufficient insulation in the ceiling and floor are frequent mistakes.

The two verifiers that mentioned problems with windows noted that builders don't always order the right windows and find out too late, and that the manufacturer sometimes labels them incorrectly (Milgard was cited as the lone example).

In general, the verifiers believed it was fairly easy to resolve any failed program requirements without adding to the construction time for the home.

Interaction with other Market Actors

Verifiers were very pleased with the BOSs. They found them to be a great resource and easy to work with. The biggest difficulty was the amount of turnover and lack of replacements. A couple of verifiers (one in Washington and one in Oregon) essentially did not have a dedicated BOS because specialists that had retired or had been fired were not replaced. Otherwise, the verifiers talked regularly with their BOS and felt the relationship worked best when the BOS has the technical knowledge to provide expertise as well.

Of the 6 verifiers that did not work at a utility, only one had significant contact with their local utility. This verifier thought that Puget Sound Energy was a great supporter of the program and couldn't say enough about the good things they were doing.

The interactions with the state certifying offices (SCOs) were positive, with the exception of the verifiers we talked to in Idaho. In the other states, no problems were mentioned about the quality assurance process. One verifier said that it is useful when the SCO occasionally goes on verifications with the verifier as a way to both do the quality assurance and provide any educational points.

In Idaho, one verifier said that that the ENERGY STAR program has been slow to respond to his requests for marketing materials. The verifier believes that part of the problem is due to back orders for the materials, and part of the problem is due to unfair treatment by the State Energy Office's distribution system. This respondent stated that many builders and other contractors are discouraged from participating in the ENERGY STAR homes program because they do not want to deal with the State Energy Office.

Upcoming Challenges

The Federal Energy Tax Credits pose the greatest challenge to verifiers, as it appears that a greater amount of energy savings is needed to qualify for the credit than is currently provided through the current BOP options. Other challenges described by verifiers include:

- Concern about Pacific Power increasing their HVAC requirements and making it more difficult to receive rebates
- Builders who are just interested in the label and not in building high performance homes
- Rural contractors have difficulties attending trainings
- Training realtors
- Having BOSs available for all areas

Overall Program Comments

The verifiers had generally positive comments about the overall program. A few didn't have any final comments, which indicated a high level of satisfaction with the program. Listed below are the comments from those that did respond:

- Several believed that the program had progressed significantly in the last year and was being responsive to problems when they arise.
- One verifier feels strongly that more trainings for builders and contractors would help a lot, and that otherwise there are no major program gaps.
- One verifier suggested that the program provide some kind of operational manual to the homeowner to keep them connected to the ENERGY STAR program after they move in.
- One verifier was critical of the job done by CSG in replacing BOSs and taking responsibility for mistakes.

3.4 PERFORMANCE TESTER INTERVIEWS

This section presents the results of interviews conducted with participating ENERGY STAR Homes performance testers. Performance testers conduct duct testing and possibly duct blaster and/or a blower door tests. The performance testers are generally either HVAC contractors or else verifiers that also provide performance testing services. The purpose of these interviews is to provide the performance tester perspective on the various ENERGY STAR Homes program components and processes and their perception of how well the performance testing requirement is accepted by builders and HVAC contractors. The analysis is generally qualitative in scope, although percentages or numbers of respondents are cited to help the reader understand the relative importance of findings.

The participating performance testers were recruited from the program tracking database maintained by PECI. The recruiting effort emphasized those performance testers that had the most experience in the program in terms of the number of tests completed for ENERGY STAR homes. A total of 9 in-depth interviews were completed with performance testers actively participating in the program. Of the people interviewed, 4 were also verifiers for the ENERGY STAR Homes program.

Table 13 shows how the tester interviews were distributed across states. The tester interviews were conducted by phone during April and May of 2006.

Table 13: Performance Tester Interview Sample By State

Builder Group	WA	OR	ID	MT	Total
Participating Testers	2	4	2	1	9
Total	**2**	**4**	**2**	**1**	**9**

Participation

Most of the performance testers interviewed (6 of 9) had been involved since the beginning of the ENERGY STAR Homes program. Four of these testers were offering testing services prior to the ENERGY STAR Homes program. When asked why they began offering duct-testing services, the most common reason the respondents stated was to participate in the ENERGY STAR Homes program.

- One respondent who works with some large builders said he saw a business opportunity and wanted to "pioneer the ENERGY STAR program" and be a "one stop shop for their builders."
- Another respondent who began offering duct testing before the ENERGY STAR program stated that they "viewed conservation as a good niche market" and they believed that duct testing would eventually be mandatory.

When asked how much of their total business is devoted to duct testing, most of the respondents stated that performance testing was a small part of their business, with the exception of one respondent who stated that testing accounted for around 50 percent of his business. One respondent noted that this is a difficult question because although performance testing by itself is small in terms of the amount of time and revenue it accounts for, it is an important factor when it comes to selling the full spectrum of the business's HVAC services.

The number of completed performance tests varied greatly among the testers interviewed. For those that stated they had been offering performance tests prior to the ENERGY STAR Homes program, the number of completed tests tended to be much higher. All of the respondents stated that almost all of the performance tests they do for new construction are for the ENERGY STAR Homes program. One respondent stated that he also performs duct testing for other programs such as Build America, Earth Advantage and Health House.

- Five respondents (two in ID, two in OR and one in WA) stated that they have completed over 50 performance tests for the ENERGY STAR Homes program.
- One respondent located in Idaho said that he expects to perform around 150 tests in 2006.

The number of builders that the performance testers work with also varied widely, from as little as five builders to over 50 builders. The respondents stated that almost all of the builders that they provide performance testing for are ENERGY STAR builders.

When asked how they expect their testing business to change in the upcoming year, all of the respondents stated that they expect it to grow. There seemed to be a general consensus that builders and contractors are becoming more conscious of energy efficiency and are acknowledging that increased building standards will become the norm sooner or later. The respondents attributed most of the increased attention to energy efficiency to the ENERGY STAR program, and in some cases to other energy efficiency programs or local utilities that are promoting energy efficiency.

- One respondent located in Oregon stated that the local utility Mid-State Electric is effectively promoting the ENERGY STAR program in its territory.
- Another respondent located in Oregon stated that he expects the industry to grow, but also warned that as more people and organizations get involved in energy efficiency things will likely become more complicated. He believes "there are too many fingers in the pie." He also expressed concern that the paperwork that comes along with different residential energy efficiency programs is becoming overwhelming and redundant, saying that the different programs "need to get on the same page."
- One respondent located in WA stated that he expects duct testing to be adopted as part of Codes and Standards. He also said that developers are beginning to require duct testing, in part because their municipalities are pushing for greater energy efficiency and sustainability.

Training

Most of the performance testers interviewed stated that their companies have between one and three staff trained to perform duct testing. The company with the most trained staff had six people trained to offer duct testing, although only three of the six actually perform tests on a regular basis. Performance testers received training from a variety of organizations, including the following sources:

- Idaho State Energy Department
- Energy Outlet
- Oregon Department of Energy
- Washington State Energy Office
- Climate Crafters
- Delta-T
- Conservation Services Group (CSG)

When asked about the effectiveness of the training, all of the respondents stated that it was helpful, but most added that it is not sufficient on its own, and that additional training is still necessary. At least three of the respondents said that they or their staff received in-house training prior to the official performance tester training and other respondents said that staff received additional training after the course.

Nearly all of the respondents thought that the hands-on fieldwork was the most important part of the training. One exception to this was a respondent who thought that written training manuals were the most important part of the training.

When asked for suggestions on how duct testing training could be improved, the respondents offered the following:

- "The training should be more of an apprenticeship program."
- "Ongoing training would be useful. One training for new personnel is not sufficient."
- "Smaller classes and more hands-on training would be helpful. It would be beneficial to spread the training out for a few days and go to multiple sites."
- One respondent suggested that a section be added to the training about the true-flow plate air test.
- Four respondents stated that the training was fine and they had no suggestions for improvement.

Performance Tester Perceptions of Builders, HVAC Contractors, and Homebuyers

The majority of the respondents thought that builders do understand the value of performance testing. Only two respondents stated that they did not believe builders understand the benefits of testing. The respondents offered a variety of comments about how they think builders view performance testing.

- One respondent who works for a full service HVAC company stated that his company encourages all builders, ENERGY STAR and non-ENERGY STAR, to have their HVAC installations tested. This respondent thought that ENERGY STAR builders were knowledgeable about the benefits of performance testing, but non-ENERGY STAR builders were less likely to believe testing is worthwhile.
- One respondent located in a high growth area in Oregon stated that builders in his area are becoming savvy about marketing the benefits of performance testing to homebuyers in order to get an edge on the competition. Another respondent who works for a full service HVAC company stated that builders like the testing because his company certifies the quality of their installations if they are tested. If any problems arise, the company will then return to fix them at no additional cost.

One respondent stated that although many builders understand the benefits of performance testing, it is still important to continue to educate builders. This respondent recommended that the ENERGY STAR program provide builders with some simple literature that explains the benefits of performance testing. Another respondent stated that builders appreciate the benefits of duct testing after they see the difference between an ENERGY STAR installation and a "standard" installation.

The respondents tended to describe the HVAC contractors as being a little more reluctant than builders to acknowledge the benefits of performance testing. One respondent thought that builders needed to do a better job explaining the ENERGY STAR requirements up front to the HVAC contractors. The respondents thought that, in general, the contractors appreciate the benefits of testing after they see their first ENERGY STAR installations tested. Most contractors fail their first test, and as a result they are able to see the amount of leakage resulting from old practices, and hence the benefits of testing. One respondent mentioned that HVAC contractors are beginning to market testing to builders as a way of distinguishing themselves from the competition.

There was a general consensus that homebuyers knew little about duct testing and were not aware of the benefits of testing.

Performance Testing Process

Most of the respondents (7 of 9) stated that a typical duct test takes between one and two hours. One respondent stated that a two-man crew usually completes a test in around two hours and another respondent stated that a typical test takes around three hours. While all of the respondents stated that they have completed tests when the ducts have failed, the percentage of failed tests varied from around five percent for experienced contractors, to 70 percent for first time installations. Most of the respondents stated that there is a quick learning curve for most HVAC contractors. After a contractor has had a few jobs tested their installations tend to improve to where they either pass the test or have some minor leaks that can be quickly fixed. The amount of time it takes to fix a problem varied (a couple of weeks to a few hours) depending on the magnitude of the problem and also if the installer needed to be called back or not.

- Two respondents who work for full service HVAC companies stated that their testers are trained to fix problems encountered during duct testing.
- One respondent stated that he encourages the contractor to be on site when the test is performed so that the contractor can fix problems on the spot.

The most common reasons for failed tests are minor leaks due to poor sealing, leaks from the air handler cabinet itself, and from post-installation damage to the HVAC system from other contractors. Post-installation damage from other contractors was stated as a major problem by three respondents. One respondent estimated that around 50 percent of the problems he has encountered could be attributed to damage caused by other contractors. This respondent thought that plumbing contractors were especially hard on the duct work. To address this issue, the respondent recommended that houses should be tested towards the end of the construction process after other work around the ducts has been completed. As one respondent explained, "Duct testing needs to happen towards the end of the project in case of problems resulting from construction." This respondent said that he usually conducts the test when the project is around 90 percent finished.

When asked what problems, if any, there are with duct testing, the respondents offered the following:

- "No problems, it is a good test."
- "It is one of the better practices that ENERGY STAR does. In reference to the idea of "sampling" a contractors work (testing only a fraction of a given contractors installations) the respondent said that "sampling is not a good option since even experienced contractors will have around a five percent failure rate."
- "It is important that the duct test is performed at the end of the construction process to check if there is damage from other contractors."
- "On larger homes, [the performance tester's] safety can be an issue when returns are in awkward places. In these situations a split system test should be permitted."
- "The installers should be there during the testing, at least for their first few tests."
- "At times the process can be cumbersome and it takes time, but the difference is dramatic. It is amazing how much leakage you can get rid of."

- “Sometimes a duct is not sealable. ENERGY STAR should provide guidelines of what to do in these cases.”

Marketing

Most of the respondents stated that they do market their participation with the ENERGY STAR program, although only one respondent stated that his business specifically markets their duct testing services. Specifically, this respondent said that his business promotes duct testing by marketing benefits such as conserving energy and improved air quality. When asked what the ENERGY STAR Homes program could do to help market duct testing, the respondents suggested the following:

- “ENERGY STAR needs to market duct testing to the HVAC contractors and get them on board so they do it as regular practice, not just for ENERGY STAR.”
- “A more consistent supply of marketing materials would be helpful, along with more co-op money for marketing.” (Idaho)
- “ENERGY STAR is doing a good job marketing, although they could hit up utilities to get larger rebates for duct testing." (Washington)
- One respondent located in Oregon recommended that ENERGY STAR should focus on advertising to homebuyers and also promote ENERGY STAR contractors as high quality installers. The respondent also recommended that ENERGY STAR get out and meet contractors and builders in person to get them on board.
- Two respondents recommended that ENERGY STAR should focus its marketing on rising energy costs and the money that ENERGY STAR homes can save.

Overall Program Experience

When asked about their overall experience with the ENERGY STAR Homes program, the respondents offered the following:

- “It’s good to have such a large-scale program that people can have a label for. Overall I think the standards are good. I also have received good technical support.” (Montana)
- “We have had a good experience with the ENERGY STAR program and should see good growth. We have already seen around a 300 percent growth.” (Oregon)
- “ENERGY STAR is doing a good job. They have done a good job explaining everything, mostly through the verifiers.” (Oregon)
- “This has been a much better program than others. The people working with the program are very knowledgeable.” (Oregon)

- "The future looks good. The program had a rocky start, but once they got their feet planted things started to pick up a lot of momentum." (Oregon)
- "Our experience has been pretty good, although it is confusing to figure out who is who in the program. The program has also been having a problem replacing the Building Operation Specialist in the state." (Washington)
- "Our experience has been good. We got in at the ground floor and it has been a good learning experience for us. It has benefited the company and also lends credibility to the company." (Washington)
- When asked if there was anything about the program that was unclear or confusing, all of the respondents said they have found the program to be clear. Two respondents, who are both located in Oregon, added that there has been some confusion about who is who within the ENERGY STAR Homes program. Specifically they referred to confusion over the roles of staff at different organizations such as the Energy Trust of Oregon, the Northwest Energy Efficiency Alliance, and The Conservation Services Group (CSG).

When asked what they think will be the biggest future challenge as a performance tester, the most common response was that as the program grows it will be difficult to get new installers trained and integrated smoothly into the program. In regard to this challenge, respondents recommended conducting additional on-site trainings and also producing some simple training and reference materials for HVAC contractors. One respondent located in Washington explained that Pacific Power was thinking about increasing the HVAC efficiency standards in its territory. The respondent stated this would be a major damper to the program in the area due to the increase in cost resulting from the HVAC upgrade.

When asked if they had any final comments on the ENERGY STAR Homes program, the respondents offered the following:

- One respondent thought that the ENERGY STAR program should include ventilation standards and air quality in their criteria. In regard to this, the respondent said that "The ENERGY STAR program is a good program. So far they have been responsive to issues that have come up, but they need to address the ventilation issue."
- "We are still learning, the more we do the better we get."
- One respondent reiterated his concern that the forms required for different energy efficiency programs, including the paperwork required by the ENERGY STAR program is resulting in a lot of redundant forms and is creating a burden for contractors.

3.5 STATE CERTIFICATION OFFICE / QA INTERVIEWS

A portion of the in-depth interviews was devoted to staff at the state energy offices that work on the ENERGY STAR Homes Program. The interviewees are the Quality Assurance (QA) specialists working for the State Certifying Organization (SCO) providing the third-party certification of the ENERGY STAR Homes. The QA specialists work with the verifiers to ensure that the verification process is proceeding smoothly and the ENERGY STAR standards are being met. For this evaluation, we spoke by phone with six QA specialists in the program territory: two in Washington, one in Oregon, two in Idaho, and one in Montana.

QA Process

Each state has a different agency serving as the SCO for the program: in Oregon, the SCO involved is the Department of Energy, in Washington it is the Washington State University Energy Program, in Idaho it is the Energy Division of the Department of Water Resources (IDWR) and in Montana it is the National Center for Appropriate Technology. Moreover, the QA process varies between states. While all use a QA process to verify that homes inspected and certified by the verifier do in fact meet the ENERGY STAR requirements, the number and types of inspection visits, and the person or persons doing the visits vary.

In Idaho, all the QA inspections are conducted by a third party retained by the SCO, while in Oregon all the homes that are built through the Energy Trust of Oregon program have QA performed by a contractor. Both contractors are directed by the SCO. In Washington and Montana, SCO staff conducts inspections, as are Oregon ENERGY STAR homes outside the Energy Trust program.

Since SCOs deal extensively with verifiers, it is important to note that most of the verifiers in Oregon are affiliated with utilities – in contrast to the other states, where they are predominantly independent for-profit businesses. In addition, the performance testing/verification functions are separate in Washington, Oregon, and Montana, while they are combined in the Home Performance Specialist (HPS) role in Idaho. The Washington SCO in particular is pushing the model of having HVAC contractors test and commission their own installations rather than relying on an outside third party.

All the states have filed QA plans that have been approved by the Regional Technical Forum (RTF), and all conduct inspections and/or tests at various stages of the construction process. Washington and Oregon say the primary goal is to confirm that the installation meets the program specification; Idaho and Montana say that they also want to build a database of technical data on the performance of homes built and tested through the program.

Sampling and Scheduling

Most of the states have been conducting QA on a sample of about 10 percent of homes, but there are variations. Washington and Oregon in particular emphasize the need to inspect a higher percentage for less experienced builders/verifiers, with a corresponding reduction below 10 percent for well established verifier/builder combinations that have proven their compliance.

- In Oregon, the sampling rate averages about 10 percent, overall, but varies by verifier depending on how their homes score on a QA template developed by the Oregon SCO and also used by the other states. For verifiers whose homes consistently pass QA testing they have a smaller sampling rate; if they do not documentation of early and extensive involvement of the verifier and the homes score more marginally, they go with a higher percentage.

- Washington is sampling about 10 percent, but notes that this sampling level can only be maintained if the State Office receives a significant subsidy over and above the certification fee paid by builders to help cover the cost of the QA effort. Washington hopes to be able to reduce the sampling rate to 3 percent and make the program self-sustaining, so that the certification fee paid by the builders covers the full cost of the QA effort. However, one Washington QA specialist noted that this may be difficult, since contractor teams turn over frequently, and every new team will require training and ongoing monitoring.

- Idaho QA specialists echo that sentiment, citing their experience with the manufactured homes program. They say that if the sampling rate falls below 10 percent, builders get lackadaisical. "We learned this in manufactured housing; you have to ride them constantly on QA."

Selection of homes to inspect also varies somewhat. While Idaho and Montana use the complete program database and both Washington and Oregon are trying to use the local version of the database they have developed, all the states more often rely on direct communication with verifiers to alert them when homes are ready for the final QA.

In most states the actual inspection of selected homes is tempered by whether those selected homes are already occupied, since only Idaho does testing on occupied homes.

- A Washington QA specialist usually prints a list of completed homes the morning or the night before inspections are to be conducted, and then visits the homes to identify those that are not occupied, which are then inspected.

- The Oregon inspector will visit a subdivision with, for example, 50 homes all inspected by the same verifier and will attempt to conduct inspections on five of those. This inspector pre-selects five number one choices from the program database list, as well as five second tier alternates. He initially tries to inspect the number one choices, but inspects an alternate if a first-tier choice is occupied, making certain to cover all the stages of construction.

- In Idaho, the QA contractor conducts inspections at a pre-designated time, usually when the framing is up but the interior walls are not yet covered. After inspecting the framing, he typically returns in the next several days to inspect the insulation and then works with the Home Performance Specialist (verifier), if possible, to observe the tests. Finally, the QA contractor goes back at the end of the construction process for the complete inspection. Idaho homes are routinely subject to a QA inspection after occupancy. While a single builder and Home Performance Specialist object to having occupied homes inspected, none of the others have expressed concern. The QA Manager emphasizes that "Homeowners love it; it's never an issue".

The QA process does not appear to be creating delays in the construction process.

- A Washington QA specialist did offer two reasons why scheduling can pose a problem. First, the verifier and QA specialist must maintain good communication. Second, the tight timeline may make scheduling difficult, since there may be less than a week between completion and occupancy, especially in the Puget Sound region. This specialist adds, however, that builders do not stop for this process, and will risk the certification rather than stop.

- In Idaho, the state QA specialist notes that concern about delays has calmed down since the early months of the program, now that both builders and home performance specialists see that the process is working.

Failure Rate/Reasons

In Washington, about 1 in 7 homes do not pass the QA testing initially. Main reasons for failure include duct tightness issues (particularly the return run from the furnace to the house where it makes a blind connection through fire rock that's usually installed before the ducts, making it hard for the HVAC contractor to seal); use of rigid foam duct insulation; and leakage around the furnace cabinet. There have also been issues of inadequate blown-in insulation, where the level was not found to be up to code. Lighting also continues to be an issue in Washington, according to the QA specialist. Particularly in upscale homes, buyers are resistant to CFLs because of light quality concerns, and some homes have failed the QA inspection because they did not meet the 50 percent CFL bulbs standard.

Oregon initially had problems in as many as one-third of its homes, but the QA specialist notes that this percentage has fallen sharply, both because contractors have improved their performance and because some of the QA inspections were initially taking place before the verifier had conducted tests and worked with the builder to ensure compliance. Initial problems tended to pertain to duct tightness and incorrectly specified air conditioners or heat pumps, but the QA specialist is now finding that contractors are making the ducts tight and routinely installing 13 SEER AC units because of the new Federal standard. Oregon is also still finding some homes short on CFL bulbs even after the verifier has signed off, although all these homes are said to have been very close to the required 50%. The only other issue reported by the Oregon QA specialist centers around details that are not clearly the responsibility of a specific contractor. For example, neither HVAC nor sheetrock contractors consider it their responsibility to seal the sheet metal boot for the duct system to the drywall.

In Idaho, overall compliance thus far has been high, with the few failures attributable either to too few CFL bulbs or inadequate insulation.

The Montana QA specialist says they have had no failures to date, noting that average numbers on the blower door test are about 4 ACH, or about half the standard. He adds that lighting is still the requirement that poses the biggest challenge to builders. There is some interest in putting in ENERGY STAR fixtures, but the QA specialist says that not all the distributors carry them.

Certification

Issuance of the ENERGY STAR certificate, another function of the SCOs, usually happens within a week of the last verifier inspection. Certification typically occurs before the QA verification, and several QA specialists pointed out that issuance of certificates was not dependent on successful completion of a QA inspection for those homes selected for QA. In fact, Washington has been starting the process of generating certificates before the final verifier inspection because they believe it is important to have the labels available for homes as soon as they pass the inspection by the verifier. They now set a date for issuance of the label when the verifier initiates the home in the database and establishes an estimated completed data; 30 days before that date the labels are sent out.

On the other hand, a Washington QA inspector notes that this process has not been followed in cases where a builder's homes have repeatedly failed. In those cases, certification has been withheld until the QA inspection verifies that all issues have been addressed. The QA inspector notes that for a few builders, "it's gotten to the point where the teeth are coming out," indicating that QA inspectors are actually using the withholding of certification to ensure compliance with program requirements.

Builder and Verifier Response

Most builders are pleased with the QA function provided by the program. Washington builders that have bought into the program are pleased because they are getting a commissioning service. Builders that are less committed to building energy-efficient homes tend to see it as an annoyance and may drop the program.

The Oregon QA program manager says builders in his state also appreciate the QA, pointing out that, in practice, the general contractor may not touch the house a lot. Larger builders in particular are primarily managing and coordinating the construction process, and they welcome having someone else take a look at the house.

In Idaho, all but one builder have been receptive to the QA process, while the Montana SCO says they have taken steps to provide the verifiers and builders with feedback throughout the construction process, which builders find helpful.

Most verifiers, too, see the QA process as a useful source of feedback. However, one QA specialist in Washington commented that since verifiers set their own prices, there are always a few who do not provide for enough time to coordinate with the QA specialist and the QA process, and who are less likely to communicate with the QA specialist as a result.

Verifier Training

Since most of the QA specialists are themselves either responsible for or involved in the verifier training, they not surprisingly said the training has been well received and effective. However, one Washington QA specialist felt that there was room for improvement and that people in the verification business should be hired to do the training.

Several QA specialists suggested that verifiers could use additional training on marketing if they are to become the primary point of contact for getting builders into the program. In addition, interview respondents said that verifiers should be either trained or encouraged to be more timely in their entry of data into the database, with several (in Oregon and Montana) noting that they had encountered "ghost houses" listed in the paper or shown at an Open House as ENERGY STAR homes even though they were not in the database.

Overall Role of QA and Outlook

Three QA specialists pointed out that the QA effort has proven to be both broader in scope and more resource intensive than originally anticipated. One Washington QA specialist cited an example where the Performance Testers had not been adequately trained, so the performance testing had to be repeated several times. The verifier could not train them, so the scope of the QA person has drifted into performance testing, "I was supposed to go out and pass and fail houses. I go out there and do a lot more. Mainly because there needs to be more support. The program needs to clarify the BOS role and verifier role. Getting people in is more than just having them sign up."

Some of the challenges for the QA function – particularly into broader roles of performance testing and even builder education – appear to be the direct result of decisions made early in the ENERGY STAR Homes Northwest program design. Comments offered on this topic by three SCOs included:

- "I believe that we launched way too early…infrastructure was not even agreed upon. Lots of decisions were made under the gun and behind the eight ball."
- "There was a tendency in the beginning to undersell the requirements; 'you're almost there'. Some verifiers took that to mean they didn't need to do that much, but that's not true. Insulation needs to be code and sometimes isn't. Some companies still use duct tape, going to mastic and testing is a big deal. The expectation that it wouldn't be much work -- among everybody involved -- was just wrong."

- "The reality is marketers think up these programs and then underestimate the cost. No one ever realized the curve it took to get builders from 2 by 4 R13 walls to doing an ENERGY STAR Home, and the follow up that takes. If you have a builder already doing 2 by 6 framing and other stuff, there's less of that, but those other guys have a lot to learn. I would spend time with the builders in the field when there were three or four trips to builders a week talking to them and getting the builder up to speed. The marketing team just thinks it will happen, but it's taken a lot more time, effort, and cash."

Two QA specialists said they also play an indirect role in marketing the program, since they can help emphasize the importance of the performance testing and verification process.

- "From the QA standpoint, if I get in early and meet with builder or construction superintendent when they hear it from the person who is going to inspect it bears more weight. So if I can get out there early it makes things work out better."
- "Builders like hearing about the program requirement from the state QA person. The BOS doesn't have that credibility because they're not enforcing the standard."

As the program evolves, several SCOs foresee an expanded role for verifiers and a more limited role for the QA specialists. The Washington SCO representative said that, "If the program is going to be self sustaining it will be necessary to ask verifiers to do builder outreach on their own. The long-term market transformation model for the program entails the verifiers taking on the marketing function. We want the QA specialists to be the people who come out once a quarter."

Coordination

The biggest issues relating to coordination were raised in Oregon and Idaho.

In Oregon, there has inevitably been confusion because of the coexistence of Energy Trust and NEEA portions of the program. The QA specialist said he has often been unsure of whom to turn to and has had to call around to a broad range of people. "For example, the BOS has had [Energy Trust] overlap, so the BOS wears several different hats. It has not been altogether clear who's responsible for what, so if a [Energy Trust] BOS is talking, which hat are they wearing? It's been frustrating in the past; confusing to see which hat they were wearing and how they were melding their roles."

One coordination issue with regard to the two programs is that other verifiers enter data into the regional database, while for the Energy Trust Program they fax in the paper forms, which are then entered first into the Energy Trust database and then into the regional database. This had led to some of the "ghost houses" mentioned earlier.

While the Oregon SCO believes that overall coordination is going reasonably well, his organization would like to be more in front of the builders and have more of a mechanism to educate builders directly. "The Energy Trust folks don't have long-term relationships with the builder and may not give them as much education or feedback as we would like to see. We want to help the builders go the next steps." He believes this will happen in the future because, "as we get all the specs aligned across the region and take care of those other details, I look forward to more of an education role to help us build support for code changes."

In Idaho, there are issues with what is perceived as an effort by the program to bypass the SCO both on program requirements and on the certification process itself.

- The Idaho SCO is also concerned because the head of ResNet has, he says, been cleared to come into Idaho to offer certification and QA services. Representatives from the Idaho SCO point out that they have an exclusive contract to do this to the end of this December. They say they are just about to break this program into credibility and it will be sustainable after this year, but if somebody else comes in it will 1) reduce fees, which represent a return on the significant investment made by IDWR, 2) confuse the builders, 3) create a bias toward HERS rather than the approach approved for certification and QA by the regional technical forum.
- IDWR may leave the ENERGY STAR Homes program altogether. They say they have put in extra time and money to make this program a success, including extra time to keep builders after a previous BOS had alienated them.

Despite these concerns, the Idaho QA Program Manager says that communications with the rest of the ENERGY STAR team and other SCOs have been good, noting, "there is a ton of communication. It's a great team that works well together." The only thing he would ask for from the program is "more money for QA. They should be more realistic about what it takes."

Similar issues with the Idaho SCO were discussed in the previous MPER for this program. The evaluation is continuing to monitor this issue and it will be more fully addressed in the next MPER when we will have an expanded sample of market actor and builder in-depth interviews on which to base evaluation conclusions and program recommendations.

3.6 POST-OCCUPANCY SURVEY

This section of the report describes the results of post-occupancy phone surveys that were completed in November 2005 and February 2006. This survey was designed to collect information on initial satisfaction of ENERGY STAR homeowners that had occupied their homes for three months or more. The survey also addressed satisfaction with the ENERGY STAR lighting and collected information on whether the homeowner had removed any of the light bulbs or fixtures.

The original goal of the post-occupancy survey was to get approximately 100 completed surveys each quarter. Since the program tracking database does not have homeowner information, we needed to take the address information and do a reverse lookup to determine each homeowner's name and phone number to conduct the survey. This proved to be less successful than we had initially hoped, as we were able to match only about 25 percent of the addresses in the database. As a result of the limited sample, we were able to complete 65 surveys across the two survey waves, which is considerably less than the 200 we had planned to complete.

Due to the difficulty in obtaining phone numbers, and the need for a reliable verification of measure retention for use in the program cost-effectiveness calculations, we are discontinuing the phone version of the post-occupancy survey. The survey will be replaced with on-site verification visits, and 100 on-sites are planned for fall of 2006. These on-sites will involve verifying the installation and retention of the lighting measures and the administration of a revised version of the post-occupancy phone survey. The results of the on-site data collection effort will be reported in the final MPER scheduled for early 2007.

Selected results from the phone version of the post-occupancy survey are discussed below. Due to the small sample sizes, the results should be interpreted as qualitative findings.

Homeowner Characteristics and Motivations

Sixty-nine percent of the respondents reside in Idaho, followed by 18 percent, 9 percent, and 3 percent living in Washington, Oregon, and Montana respectively. In comparison, only 35 percent of ENERGY STAR homes have been built in Idaho through July 2006, and 35 percent have been built in Oregon. Thus the responses over-represent Idaho residents and under-represent Oregon residents in particular. The Washington and Montana response rates are roughly representative of actual building percentages.

Forty-one respondents had selected homes that were already designated as ENERGY STAR prior to their purchase, while 19 had the option to choose an ENERGY STAR home or other design from the builder. Most respondents (65 percent) had lived in their home at least 6 months.

Table 14 shows that the primary reason homeowners selected an ENERGY STAR home was to save money on energy bills. The most common responses in the "other" category related to the home's desirable location/neighborhood, a pleasing layout or floorplan, or a desire to support the ENERGY STAR brand and the concept of energy efficient homes. In a separate question regarding concerns about purchasing an ENERGY STAR home, 71 percent of respondents said that they had no concerns.

Table 14: Reason for Purchasing an ENERGY STAR Home

Response (n = 65)	% Of Respondents
To save money on energy bills	32%
Builder recommended	9%
Better value	9%
Realtor/sales person recommended	5%
Solid construction	5%
Concerned about the environment	3%
Other	35%
Don't know	14%

Q: Why did you decide to purchase an ENERGY STAR home?

Homeowner Satisfaction

When asked to rate their overall satisfaction with their ENERGY STAR home, where a score of 5 = extremely satisfied and 1 = extremely dissatisfied, 86 percent of respondents gave a score of 4 or 5, and no respondent gave a score less than 3 (see Table 15).

Table 15: Overall Satisfaction with ENERGY STAR Home

Response (n = 65)	% Of Respondents
5 – extremely satisfied	54%
4	32%
3	6%
2	0%
1 – extremely dissatisfied	0%
Don't know	8%

Q: On a scale of 1 to 5, please rate your overall satisfaction with your ENERGY STAR home, where 5 is extremely satisfied and 1 is extremely dissatisfied.

In separate questions (responses not shown) 88 percent of ENERGY STAR homeowners said they would recommend an ENERGY STAR home to other prospective homebuyers. The greatest overall benefit is perceived to be energy savings followed by better insulation. Relatively few respondents noted improved windows, tight ductwork, or improved air quality.

Forty-six respondents (71 percent) said there was no aspect of their ENERGY STAR home that did not meet their expectations. Among those that did perceive problems, five respondents (8 percent) mentioned air quality/circulation and four respondents (6 percent) mentioned the lighting.

Lighting Satisfaction and Retention

Table 16 shows how the respondents rated their experience with the lighting specifically, and indicates that satisfaction with the lighting is lower than satisfaction with the entire home product. The main reasons for dissatisfaction with the lighting are insufficient brightness (12 percent) and that it takes too long to start (11 percent).

Table 16: Satisfaction with ENERGY STAR Home Lighting

Response (n = 65)	% Of Respondents
5 – extremely satisfied	40%
4	29%
3	23%
2	6%
1 – extremely dissatisfied	2%

Q: On a scale of 1 to 5, where 5 is extremely satisfied and 1 is extremely dissatisfied, how satisfied are you with the lighting in your home?

The second wave of the post-occupancy survey collected the most detailed answers regarding the removal and replacement of the lights (additional questions were added from the first wave of the survey). These results are presented in Table 17 but due to the very small sample sizes the results should be viewed as qualitative.

Fifteen respondents (47 percent of the second wave) indicated that they have replaced lighting since moving in, and most of these (54 percent) had replaced three or fewer lights. Of these fifteen respondents, three indicated that they had replaced CFL lamps; ten said they had replaced incandescent lamps, and the remaining two respondents did not know what type of light they replaced.

Table 17: Type of Bulb Replaced (Second Survey Wave)

Response (n = 15)	% Of Respondents
CFLs	20%
Incandescents	67%
Don't know	13%

Q: For the bulbs you replaced, were they CFLs or normal incandescent light bulbs?

When asked what type of bulbs they had installed as replacements, four respondents stated that they installed a CFLs and eight installed incandescent lamps. One respondent indicated that they had used both CFLs and incandescent lamps as replacements.

Table 18 shows the main reasons for replacing the lighting among respondents who replaced any bulb or fixture (respondents could choose more than one answer). Note that this table includes both survey waves and includes all respondents that replaced either CFLs or incandescents.

Table 18: Reason for Replacing Lighting (Both Survey Waves)

Response (n = 25)	% Of Respondents
Burn out	40%
Not bright enough	32%
Didn't like light color	12%
Did not like look	12%
Took too long to start	8%
Other	8%

Q: Why did you replace the lighting?

Of the fifteen respondents in the second survey wave that replaced lighting, three had replaced CFLs and all of these respondents said that the CFLs were replaced due to burnouts. The respondents that replaced CFLs all indicated that they replaced the CFLs with a combination of CFL and incandescent bulbs.

Post-Occupancy Survey Summary

In general, it appears the homeowners are very satisfied with their ENERGY STAR homes. While there has been some replacement of lighting (both CFLs and incandescents), the small survey sample sizes make it difficult to draw strong conclusions. The on-site data collection effort planned for 2006 is defined to provide more definitive data on the retention of lighting measures and these results will be presented in the next MPER.

4. CONCLUSIONS AND RECOMMENDATIONS

The following general conclusions are drawn from the data sources and analysis presented in this report:

- **Participating builders that are active in the program are generally satisfied with the ENERGY STAR Homes Program.** The builders enjoy the market differentiation that the program provides, and at least a third of the builders said that there is customer demand for ENERGY STAR features. Some builders also expect ENERGY STAR to become more important to homebuyers if energy prices continue to rise. Builders also indicate that verifiers and Building Outreach Specialists (BOSs) play an important role assisting builders with the program. The verifiers and BOSs provide a wide range of services to the builders, including technical assistance, help understanding the program requirements, and training to contractors.

- **Performance testers have also been pleased with the ENERGY STAR Homes program.** Performance testers perform duct tests and sometimes duct blaster and/or blower door tests on ENERGY STAR Homes as part of the home certification process. The testers we interviewed indicated that the requirements have been clear and that the implementation of the ENERGY STAR Homes program has been smooth.

- **HVAC companies are beginning to use performance testing as a way to differentiate themselves from their competition.** This was stated mostly by respondents who work for HVAC companies in high growth areas where there is more activity in the ENERGY STAR Homes program. Respondents stated that they are marketing themselves as a "one-stop shop" for ENERGY STAR builders. They are also encouraging non-ENERGY STAR builders to include performance testing when they have an HVAC installation. Although the testing itself accounts for a small part of the overall business for full service HVAC companies, at least one respondent believes that the testing is a valuable service that helps the company sell more jobs.

- **Builders and contractors acknowledge the benefits of performance testing.** In general, respondents stated that they have had little difficulty working with builders, and that the builders appreciate the benefits of duct testing. One respondent stated that builders like that his HVAC company guarantees the quality of the installation when performance testing is included. For the most part, respondents also thought contractors appreciate the benefits of duct testing, although it sometimes takes a few demonstrations before they are willing to change their past practices. Builders have also indicated that they are able to market the benefits of performance testing to prospective homebuyers.

- **Many performance testers noted that the timing of the duct tests is an important issue.** Many duct test failures are due to post-installation damage from other contractors and respondents recommended that duct tests be performed towards the end of the construction process to account for this issue.

- **Performance testers believe that the current level of training provided by the program is not sufficient on its own.** Although they did think the training was useful, there was a general consensus that without some sort of in-house apprenticeship, the training would not be sufficient to prepare somebody for the field. Respondents recommended extending training courses to allow for a greater number of on-site trainings or require an apprenticeship before becoming a performance tester. Most of the respondents stated that they either had extensive in-house trainings before they took a performance tester training course, or their company provided continuing training after they took the course.

- **The program requirements do not pose significant barriers for participating builders.**[6] While the requirements were not considered problematic for the builders we talked to, it did appear that some builders may not fully understand all of the requirements and the benefits of some of the home specifications. In general, builders were not bothered by the lighting requirement, and many builders said they expected it to be part of the program. Several of the builders were not aware that dedicated CFL fixtures could be used to meet the lighting requirement, however. Although most of the builders interviewed said they believed that duct testing was an important aspect of the program, around a third of the respondents said that they were not aware of any benefits of duct testing.

- **Builders are pleased with the marketing support that the ENERGY STAR Homes program provides.** The majority of builders said that they take advantage of the marketing materials that the program provides and believe they are important tools for explaining the benefits of ENERGY STAR homes to customers.

- **Low ENERGY STAR Homes production in Washington will likely cause the program to miss its goal for 2006.** As of September 2006, the program was at 79 percent of its overall homes goal for 2006 assuming that all the initiated homes are completed by the end of the year. The shortfall is primarily due to Washington, where only 52 percent of the homes goal for 2006 had been met as of September.

- **Homebuyers are purchasing ENERGY STAR Homes primarily to reduce their energy bills.** Saving money on energy bills was the most common reason cited by homebuyers on why they purchased an ENERGY STAR home. Other homebuyers stated that they bought an ENERGY STAR home based on the

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[6] The perception of program requirements among nonparticipant builders will be addressed in the next MPER.

builder or realtor recommendation. Homebuyer motivations will be examined in more detail with the larger survey efforts planned for the final MPER. These surveys will include a phone survey of recent new home buyers and in-depth interviews with real estate agents and sales reps for ENERGY STAR builders.

Based on the evaluation findings, we make the following recommendations:

- **Increasing the production of ENERGY STAR Homes in Washington needs to become a high priority.** As discussed above, the overall shortfall of ENERGY STAR homes in 2006 is primarily due to Washington, where only 52 percent of the homes goal for 2006 had been met as of September. Increasing production in Washington needs to be a high priority for the remainder of the year if the homes goal is to be met.

- **Investigate issues relating to lighting fixtures and the lighting requirement.** One builder mentioned that when he installs a decorative chandelier with many non-ENERGY STAR bulbs, he is forced to add extra lighting fixtures to the house so that he can meet the 50 percent requirement of the ENERGY STAR program. The extra fixtures that are added have the potential to make the house less energy efficient than otherwise, since this essentially adds unnecessary bulbs to the home.

  In addition to the chandelier issue, 4 of 16 builders we interviewed were unaware that dedicated CFL fixtures could be used to meet the lighting requirement. Additional information should be provided to builders so that they are aware that both CFLs and dedicated CFL fixtures are options for ENERGY STAR homes.

- **Lighting retention should receive additional study.** There is evidence from the post-occupancy survey that at least some of the CFLs installed in the homes are being removed due to burnouts, but this is based on a very small sample. This issue will be addressed in greater detail through the on-site data collection effort planned for fall of 2006.

- **Promote the potential benefit of ENERGY STAR Homes in the permitting process.** One builder mentioned that the local government where he works (in Washington) awards building permits based on a point system. Developments that will be rated as ENERGY STAR receive additional points, making it easier to receive a building permit. This kind of incentive has the potential to be attractive to builders, especially larger developers who must go through a more rigorous building permitting process. The program should use this as a marketing tool in areas where it currently exists and encourage permitting agencies in other areas to begin offering preferences for ENERGY STAR homes.

- **Performance testing training and education should be increased.** The performance testers we interviewed emphasized the need for training that is ongoing rather than a single training session. The testers also emphasized the value of the hands-on fieldwork as part of their training. In addition, one third of the builders we spoke with did not know the benefits of duct testing or did not believe that any existed. This indicates that the benefits of testing need to be better communicated to builders, and that more on-going training opportunities are needed for performance testers.

- **The use of an independent forecast of housing starts to determine program goals should be considered.** F. W. Dodge is a commercially available source of home construction data and also provides forecasts of the housing market in upcoming years. Rather than have the program estimate housing starts during the current year to determine goals, we recommend that the program consider purchasing Dodge data. This will enable the yearly goals to be determined independently, as the housing starts estimate for the year will be determined through third-party source not affiliated with the program.

- **Marketing of ENERGY STAR homes directly to consumers should be increased.** Builders cite the lack of consumer awareness as one of the biggest barriers for ENERGY STAR homes. Several builders also recommended that training classes be offered to realtors so that they can learn to sell ENERGY STAR homes more effectively. Finally, several builders mentioned that homebuyers do respond to the benefits of duct testing when they are promoted which suggests that these benefits should be included in any consumer marketing campaign.

APPENDIX A: GLOSSARY

Annual Fuel Utilization Efficiency (AFUE). A numeric efficiency rating for furnaces. An AFUE rating of 0.90 or higher for gas furnaces and 0.80 for propane heating is needed to qualify for the ENERGY STAR Homes program.

Air Changes per Hour (ACH). Refers to the number of times air is circulated within a home within an hour. Minimum levels are established to help combat mold due to tight building envelopes required for efficient homes.

Builder Option Package (BOP). A specified list of measures and building practices that builders can follow to build an ENERGY STAR-qualifying home.

Building Outreach Specialist (BOS). A representative of the program that recruits builders and provides technical assistance.

Compact fluorescent light (CFL). A type of lightbulb that is more energy efficient than a regular incandescent bulb and has a longer equipment life. A CFL often has a distinctive twisted design.

CFL fixture. A lighting fixture where only CFL lamps can be used. These fixtures usually require pin-based CFL lamps so that the bulb cannot be swapped out for incandescent bulbs.

Conservation Services Group (CSG). One of the companies implementing the ENERGY STAR Homes program, under the direction of the prime contractor PECI.

Duct Test. General term referring to either a duct blaster test (where only the ductwork is tested for leaks) or a blower door test (where the whole house is tested for leaks).

Earth Advantage. A sustainable buildings program originally created by Portland General Electric.

Energy Factor (EF). An EF value shows the efficiency of water heaters. For gas water heaters, an EF of 0.60 or better is required, while electric water heaters require an EF of 0.93 or better.

Energy Trust of Oregon (ETO). Energy Trust of Oregon implements energy efficiency programs in Oregon using public benefits funds collected from several utilities. Energy Trust of Oregon also helps sponsor and implement NEEA's ENERGY STAR Homes Program within Oregon.

HVAC. Refers to heating, ventilation, and air conditioning systems and is used as a generic term for heating and cooling equipment.

Heat Pump. A type of air conditioner that will also provide heat during the winter.

Heat Recovery Ventilator (HRV). An HRV provides an efficient method for bringing in fresh air into a building while removing stale air. The HRV will preheat the incoming air in the winter and cool the incoming air in the summer.

Home Performance Specialist. The job title used for verifiers in Idaho.

Heating Seasonal Performance Factor (HSPF). A measure of efficiency for heat pumps. The ENERGY STAR Homes program requires an HSPF of 8.0 or better to qualify for the program.

Market Progress Evaluation Report (MPER). MPER is the acronym used by NEEA for all its evaluation reports.

NEEA. The Northwest Energy Efficiency Alliance is the agency sponsoring the ENERGY STAR Homes Program. See the website www.nwalliance.org for more detailed information.

Performance Testing. A more general term used for duct testing and could involve a duct blaster and/or a blower door test.

Portland Energy Conservation, Inc. (PECI). PECI is the company that has been hired by NEEA to implement the ENERGY STAR Homes Program for NEEA.

Quality assurance (QA) specialist. A quality assurance specialist works for the State Certifying Organization to monitor and verify the work completed by the verifiers.

State Certifying Organization (SCO). An SCO is the agency that provides the final certification for an ENERGY STAR Home.

State Energy Office (SEO). An SEO is the state government office in charge of energy issues for the state (such as the Oregon Department of Energy). In the case of Oregon and Idaho, the SEO is also the SCO for ENERGY STAR homes within the state.

Seasonal Energy Efficiency Rating (SEER). A numeric rating system for air conditioner and heat pump efficiency. A SEER rating of 13 is required by the ENERGY STAR Homes program.

Technical Compliance Option (TCO). A TCO are additional specifications within a BOP that allow for different equipment to be installed and still meet the ENERGY STAR Homes specification requirements.

Verifier. A verifier provides third-party verification that the requirements for an ENERGY STAR home are being met.

APPENDIX B: ENERGY STAR HOMES NORTHWEST SPECIFICATIONS

Table 19 provides a summary of the two prescriptive Builder Options Packages (BOPs) for single-family, site-built homes. The ENERGY STAR Homes Northwest package was designed to include efficiency measures that would result in a level of performance that was a minimum of 15 percent better than that required by codes in the region. It is also designed to include efficiency improvements in all major end-uses including space heating and cooling, water heating, lighting, and appliances. Testing the HVAC and duct systems for leaks is also required using ENERGY STAR Northwest performance testing specifications. Finally, the requirements were designed to maximize the marketing impact by linking to as many ENERGY STAR branded components as possible, from the heating and cooling system to lighting and appliances.

Table 19. ENERGY STAR Homes Northwest Technical Specifications

Component	**BOP 1** **(Heat Pump/Gas Furnace)**	**BOP 2** **(Zonal Electric/Propane)**
Ceiling	R-38 Std	R-38 Std
Wall	R-21 Std.	R-21 Std. + 2.5
Floor Insulation	R-30	R-30
Unheated Slab Below Grade	R-10	R-10
Windows	U-0.35	U-0.30
Heating System	8.0 HSPF 0.90 AFUE	N/A / 0.80 AFUE
Ventilation System	Central Exhaust	HRV 70%
Air Conditioning System	SEER 13	SEER 13
Duct Insulation	R-8	Electric: N/A Propane: R-8
Duct Sealing	Mastic	Electric: N/A Propane: Mastic
Duct Tightness	< 0.06 CFM per ft_2 Floor OR 75 CFM Total @ 50 Pa	Electric N/A Propane: same as BOP1
Envelope Tightness	7.0 ACH @ 50 Pa	2.5 ACH @ 50 Pa
Water Heating	Electric 0.93 EF / Gas 0.60 EF / (> 60 gal.)	Electric 0.93 EF / Gas 0.60 EF / (> 60 gal.)
Appliances	All built-ins are ENERGY STAR	
Lighting	> 50% of sockets either ENERGY STAR lamps or fixtures	

To further increase the flexibility of these requirements, there are also several Technical Compliance Options (TCO) that are allowed within each of the two BOPs:

- TCO #1 substitutes perimeter insulation for floor insulation in homes with crawlspaces.
- TCO #2 replaces the SEER 13 air conditioning unit with a SEER 12 unit in exchange for additional upgrades in the building shell or equipment.

- TCO #3 utilizes the U.S. EPA's Advanced Lighting Package[7] in place of the current BOP standard.

- TCO #4 allows for a gas hydronic heating system for use with BOP #1 and includes several modifications to the efficiency requirements for water heating and insulation depending on the type of system.

- TCO #5 allows for an electric hydronic heating system for use with BOP #2 and includes several modifications to the efficiency requirements for water heating and insulation depending on the type of system.

- TCO #6 allows for U-value trade-offs within BOP #1.

- TCO #7 allows for U-value trade-offs within BOP #2.

- TCO #8 allows for trade-offs between hot water heater efficiency and insulation requirements.

- TCO #9 provides for hybrid gas unit heaters with electric resistance zonal heating.

- TCO #10 allows for hybrid "ductless split" heat pumps with electric resistance zonal heating

- TCO #11 provides for propane furnaces (90 AFUE minimum)

These TCOs help the program to include a greater range of equipment options, many of which are driven by alternative building practices.

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[7] The U.S. EPA Advanced Lighting Package requires that 50 percent of high-use rooms and outdoor lights must have ENERGY STAR fixtures. In addition, all ceiling fans must be ENERGY STAR and 25 percent of medium-use and low-use rooms must have ENERGY STAR fixtures.

APPENDIX C: INTERVIEW GUIDES / SURVEY INSTRUMENTS

ENERGY STAR Builder Interview Guide

Hello, my name is ____________ calling on behalf of ECONorthwest, an energy research firm based in Portland. First, I want to assure you that this is not a sales call. The Northwest Energy Efficiency Alliance has asked us to help them better understand how well the current ENERGY STAR Homes Northwest is operating. Could I speak to ______________________ or could I speak to the person at your firm most involved with the ENERGY STAR Homes program?

[IF NECESSARY:] This survey is extremely important to the Alliance's understanding of the new homes market, and will help in the design and delivery of programs that will directly affect firms like yours. We're willing to work around your company's schedule to find a time when the appropriate person at your firm can speak with us for about twenty minutes.

[IF NECESSARY:] The Northwest Energy Efficiency Alliance is a non-profit corporation supported by electric utilities, public benefits administrators, state governments, public interest groups and energy efficiency industry representatives. These entities work together to make affordable, energy-efficient products and services available in the marketplace. The Alliance is currently offering a northwest regional version of the national Energy Star homes program. That's why they are looking for input from new homebuilders in the Pacific Northwest.

[WHEN CORRECT PERSON IS ON-LINE:]
Name: ______________________
Company: ______________________
Title: ______________________
Phone: ______________________

Program Participation

First, let me ask you a few questions on how you decided to participate in the program and then we'll talk about the various steps involved in the program.

1. Approximately how many total homes do you expect to build this year?

2. Of these, will they all be ENERGY STAR, or will ENERGY STAR be offered as a possible option on some? (Get estimate on how many ES if appropriate)

3. What do you consider to be the biggest advantages to you from participating in the ENERGY STAR homes program?

4. What types of program support do you find the most valuable? The least valuable?

   List of possible support areas:
   Verification/Inspection of homes
   Co-op advertising

Incentives
PR support
BOS
Marketing materials [probe for specifics on which materials they found helpful]
PT Training for HVAC contractors
Training for contractors
Training for builders

Program Requirements

5. How easy or difficult has it been for you to find information regarding program requirements and participation? Why do you say that?

6. How will the change to SEER 13 air conditioners affect you?

7. There are many different options (or BOPs) for builders to qualify their homes for the program. How does that affect you? Do you use one particular option for all of your homes?

8. What individuals or organizations have provided you with the most information and assistance about the program? Then probe for BOS vs. verifier, HPS, duct tester, utility, etc.

Lighting Requirement

9. What about the lighting requirement, has this been an issue for you?

10. What was your opinion regarding the lighting requirement when you first started the program? Did you think that you would need to meet the lighting requirement using fixtures only?

11. Has your opinion of the lighting requirement changed since you started the program? Was meeting the lighting requirement easier or harder than you expected?

12. Given all of the ENERGY STAR home requirements, how big of an issue is the lighting requirement for you relative to the requirements?

13. Where do you buy the CFL lamps and fixtures you use for these homes? (Probe on type of store (big-box, hardware, lighting showroom) and purchase process details)

14. On average, how much is the ENERGY STAR lighting requirement adding to the cost of your homes?

15. What has been the biggest challenge for you in participating in the ENERGY STAR Homes program? What has been the toughest ENERGY STAR requirement for you to meet?

16. Have you had any problems finding equipment needed to meet the ENERGY STAR requirements (probe specifically for CFL bulbs and fixtures)

17. What additional types of assistance would you like to see provided to builders by the ES Homes program?

18. Does your utility support the program? What kind of support do they provide? How important to you is that support in participating in the program?

19. Are you aware of other energy efficiency related programs for homes? Do you also build to any of their requirements? Would you say the programs complement one another or are more in opposition to each other? Why?

Contractor Training

20. Has your HVAC contractor been trained? How beneficial has the ENERGY STAR training been for your HVAC contractor? Do you feel that they were brought up to speed in a timely manner? Have there been any problems?

21. We are also talking to HVAC contractors in our interviews and would like to talk to the contractor you use since you are participating in the ENERGY STAR homes program. Could we get the company name and a contact person of your HVAC contractor (try to get phone number too)

22. We are also going to talk to electrical contractors, could we get contact information for your electrical contractor?

23. We are also going to talk to electrical contractors, could we get contact information for your electrical contractor?

Performance Testing

Now I'd like to ask a few questions regarding the performance testing of ducts that is required by the ENERGY STAR homes program.

24. Who does the duct testing for your homes?

25. What do you think are the benefits of duct testing to the builder?

26. What are the benefits to the homebuyer of duct testing? Do you believe that the homebuyer is aware of these benefits?

27. Do you specifically market the fact that the ducts have passed (or will be required to pass) the duct test when promoting your homes to prospective buyers? Do you promote the benefits of duct testing?

28. How long does the duct test take? Have you had any problems locating a tester or scheduling a time for them to come and do the tests?

29. What are the disadvantages with duct testing, if any

30. How would you rate the value of duct testing relative to its cost?

31. Have any of your homes failed the duct test at some point? Why did they fail and what was done to correct the problem?

32. Do you have any other comments about the duct testing process?

Verification Process

Next I'd like to ask you some questions about the verifier (in Idaho – Home Performance Specialist) you have for your ENERGY STAR homes

33. How did you find a verifier/Home Performance Specialist for your homes? (Probe source, did verifier approach them, did they talk to more than one verifier)

34. Approximately how many ENERGY STAR homes have you had verified to date?

35. In general, how well has the verification process gone?

36. Does your verifier/HPS provide you with any other types of building assistance in addition to verifying the various ENERGY STAR Homes requirements (If yes, get details)

37. Have any of the ENERGY STAR Homes you built failed any of the verification stages? (If so, find out specific issues.

38. If yes, for those that failed, how long did it take to fix the problem and then have the verifier/HPS come back and complete the verification?

39. Have there been any delays in construction due to the verification process? If so, what do you think should be done to help improve the verification process to prevent delays?

40. What are the disadvantages (if any) of the verification process?

41. Do you think that building homes to the ENERGY STAR specifications reduces callbacks?

Quality Assurance / Certification

42. The ENERGY STAR Hones program has a state organization that randomly visits a sample of homes to check up on the Verifier/Home Performance Specialists work. Have you had any interactions with the program quality assurance that oversee the certification process? (If yes, get details)

43. How well did the QA process go? Did this cause any delay in the process?

44. Have you received an ENERGY STAR label for any of your homes

45. How long did it take from the time your Verifier/Home Performance Specialist approved the home to the time you received the label on the home. Were there issues with this process?

Marketing

Finally, I'd like to talk to you about how you market your ENERGY STAR homes.

46. Do you sell your homes through your own sales reps or through real estate agents?
    Sales reps
    Real estate agents
    Other

47. Do you feel your sales reps are knowledgeable about the program? Do you feel they are effectively selling the advantages of an ENERGY STAR home?

48. Which methods do you use to promote your ENERGY STAR homes?
    Newspaper ads
    TV/Radio
    Real estate ads
    Outdoor signs
    Model homes
    Brochures / Sales materials
    Internet
    Other

49. Which ENERGY STAR benefits do you/will you promote when marketing these homes?

50. What do you think are the biggest marketing challenges for ENERGY STAR homes?

51. What role does lighting play in customer's decision to choose ES?

52. What do you think the ENERGY STAR homes program should do to effectively market the benefits of an ENERGY STAR home?

53. Do you feel that you have been well informed by the program regarding marketing opportunities?

54. They are co-op advertising, signage for outside and inside the house, brochures, home owner guides for when the homeowner moves in.

55. Which ones have you used, found most helpful? Do you have any issues/concerns with any of the marketing support?

Those are all the questions I have for you today. Thank you very much for your time.

ENERGY STAR Verifier / PT Interview Guide

Hello, my name is ____________ calling on behalf of ECONorthwest, an energy market research firm based in Portland. First, I want to assure you that this is not a sales call. The Northwest Energy Efficiency Alliance has asked us to help them better understand the market for energy-saving features in the residential new home new home construction market. Could I speak to ____________________ or could I speak to the person at your firm most involved in supplying the residential new construction market?

[IF NECESSARY:] This survey is extremely important to the Alliance's understanding of the new homes market, and will help in the design and delivery of programs that will directly affect firms like yours. We're willing to work around your company's schedule to find a time when the appropriate person at your firm can speak with us for about twenty minutes.

[IF NECESSARY:] The Northwest Energy Efficiency Alliance is a non-profit corporation supported by electric utilities, public benefits administrators, state governments, public interest groups and energy efficiency industry representatives. These entities work together to make affordable, energy-efficient products and services available in the marketplace. The Alliance is currently in the process of developing and offering a northwest regional version of the national ENERGY STAR homes program. That's why they are looking for input from builders, distributors, and other firms who operate in the Pacific Northwest new homes market.

[WHEN CORRECT PERSON IS ON-LINE:]

Name: ______________________
Company: ______________________
Title: ______________________
Phone: ______________________

Hello, my name is ____________ and I'm calling on behalf of ECONorthwest, an energy market research firm based in Portland. First, I want to assure you that this is not a sales call. The Northwest Energy Efficiency Alliance has asked us to help them better understand the market for energy-saving features in the residential new home construction market. We are talking to verifiers/home performance specialists to understand their experience in relation to the ENERGY STAR Homes program. Can I confirm that you are engaged in verifications for the ENERGY STAR Homes program?

If YES, continue. If NO, thank and terminate:

Introduction and Business Scope

I'd like to start with some general information about you and your company.

1. When did you become a verifier [Home Performance Specialist/Idaho]?

2. Do you have a contract to be a verifier with another organization, or are you an independent contractor?
   a. Utility contract
   b. CSG or Earth Advantage contract (PGE's Energy Services Group (ESG))
   c. Independent Contractor

3. Approximately how many ENERGY STAR home verifications have you done to date?

4. Do you also perform duct testing on ENERGY STAR homes?
    a. Yes, also do duct testing
    b. No duct testing

5. Do you offer any other services to builders or contractors that are involved with building homes?

6. How much of your business is from ENERGY STAR home verification?
    a. Verification:__________
    b. Duct Testing:_________
    c. Other:______________

7. Do you expect this to change in the upcoming year? In what way? (Probe for expectations of work as a verifier, will verifications increase or decrease, etc.)

8. How big of a business opportunity do you consider verification to be?

9. How many different builders are you currently working with as a verifier for the ENERGY STAR homes program? [IF ALSO DUCT TESTER, ASK] Of these, how many do you do duct tests for?

10. How much do you charge for your verification services? (Per home)

11. Do you expect your fee to change in the upcoming year?

12. IF INDEPENDENT CONTRACTOR, ASK:] For your current builder clients, how did they find you? How do you go about recruiting builders for your services? Do you actively market your verification services to builders? If so, what aspects do you emphasize?

13. What kinds of assistance would help you more effectively market these ENERGY STAR benefits to builders?

14. What do you think the ENERGY STAR program should be doing to help market ENERGY STAR homes? (Probe for suggestions for marketing to builders, contractors, and homebuyers)

Training

Next I'd like to ask you some questions specifically about your experience with the ENERGY STAR Homes program training:

15. Who trained you to become a verifier for the ENERGY STAR Homes program? Do you feel that the training adequately prepared you to verify ENERGY STAR homes?

16. What aspects of the training do you think were most valuable? Least valuable? How, if at all, could the training have been improved?

17. How about builders, have you had any experience with the training offered to builders regarding ENERGY STAR? How do you feel this training is going? (Probe for opinion on if builders are adequately trained on the various ENERGY STAR requirements including duct testing, proper HVAC installation, lighting

18. Do you have any suggestions for the program for improving the builder training?

19. How about contractors, have you had any experience with the ENERGY STAR Homes training provided to them? Do you feel that this training has been effective?

20. Do you have any suggestions for improving contractor training?

Verification Process Coordination

Next I'd like to ask you some questions about the verification process and how you coordinate your activities with builders and others involved in the process.

21. How would you characterize your relationship with your builders? How often do you talk? (Probe for if relationship is cooperative or adversarial).

22. How did the builders you work with find you?

23. What type of marketing, if any, do you do to attract builders? (Probe for channels, methods)

24. What type of assistance would help you market more effectively (Probe)

25. How do you coordinate the timing of the verification visits with the builder? (Probe for how well they are kept informed of building stages and how quickly they can get this information, their use of online database, timing of information and if it's kept up-to-date.)

26. How long does a typical verification visit last? (Probe for activities, what they look for, what they discuss with the builder, etc.)

27. Have you used the program's online database? Has this been helpful? (Probe for details, particularly problems and suggestions for improving)

28. How many of the homes you have worked with failed their verification? What is the most common reason(s) that homes you've tested have failed verification? (Probe for specific areas where they failed)

29. For those that failed, how long did it take for them to fix the problem? (Probe for specifics; differences according to different builders, different problems?)

30. Have you come back out to complete the verification for homes that failed the initial verification? Did they pass the 2nd time? (Probe for specifics)

31. Based on your experience, which of the ENERGY STAR requirements, if any, pose (or would pose) significant challenges to builders and other contractors? (Probe for ventilation, testing, equipment availability, difficult installation, need to do mastic sealing of ducts, etc.)

32. Have you worked with the Builder Outreach Specialists from the ENERGY STAR program? What kind of interactions have you had? (Probe for how well this has gone)

33. Have you worked with the utilities? If so, what has been the utility involvement? How has the process worked for you? (Probe for benefits and problems)

34. Have you had any interactions with the State Energy Offices that provide the quality assurance (QA) oversight for verifiers?

35. How does the state coordinate its QA activities with you and your builders? How has this process worked so far? Any suggestions for improvement?

36. How about certification, have you had any ENERGY STAR homes go through the entire certification process yet? Once you approve a home for certification, is the SEO getting the certificate and the label to you/the builder in a timely manner?

37. Have you received any technical support from the state certification office? Did this go well?

Duct Testing Module (to duct testers only)

Now I'd like to ask you some questions about your duct testing work

38. How long have you been doing duct tests?

39. Why did you start offering duct testing services?

40. Where did you receive training to become a duct tester?

41. Did this training adequately prepare you for testing in the field?

42. What was the most valuable part of this training? Least valuable?

43. Do you have any suggestions on how the duct tester training could be improved?

44. How many duct tests have you done on new homes to date? How many of these were for ENERGY STAR homes (probe for if they were for other programs like Earth Advantage)

45. How, if at all, do you expect your duct testing business to change in the upcoming year? (probe for reasons on any expected increase or decrease)

46. On average, how many duct tests a month do you perform? How many can you do in a single day?

47. How long does it take to do a duct test?

48. Have you done any tests where the ducts failed the first time? (Probe for reaction by HVAC contractor, builder to failed test)

49. For those homes that fail tests, how long before you returned to re-test the ducts? (Probe for potential scheduling issues)

50. What are the most common reasons for ducts to fail their test? (Probe for particular areas in the duct system, types of equipment, systems, or home designs that are more prone to fail, etc.)

51. In general, what are the problems, if any, with duct testing?
    1) Time consuming
    2) Tests inaccurate, do not reflect actual equipment performance
    3) Too expensive
    4) Delays in scheduling testers
    5) Testers not available in area
    6) Lack of competence among testers
    7) Other, please specify:____________________________
    8) No problems
    88) Don't know
    99) Refused

52. Do you think builders believe that duct testing is worthwhile? How about the HVAC contractors?

53. Do you think that builders are knowledgeable about the benefits of duct testing? How about homeowners?

54. Do you actively market the benefits of duct testing?

55. If so, who do you market to? What benefits do you emphasize?

56. Is there anything else the ENERGY STAR Homes program can do to help you better market or perform the duct tests?
    1) More training on how to do duct sealing and testing
    2) Materials that show dollar savings for duct testing
    3) Materials that show other benefits of duct testing
    4) Advertising to build home buyer awareness and interest in ENERGY STAR
    5) Other ____________________________________

Overall Program Interaction/Conclusions

Finally, I'd like to conclude by asking you a few questions about the overall program...

57. Overall, how would you rate your experience with the ENERGY STAR Homes program? Why do you say that? (Probe fully.)
58. Is there anything about the program that is confusing/unclear?
59. What do you think will be the biggest future challenges for you as a verifier?
60. What can the ENERGY STAR Homes program do to help address these challenges?
61. Do you have any final comments on the ENERGY STAR Homes program?

Those are all the questions I have for you today. Thank you very much for your time.

APPENDIX D: CERTIFIED AND INITIATED HOMES BY STATE

Below are charts showing the total number of certified and initiated homes by month and by state.

Figure 3: Certified and Initiated Homes by Month - Idaho

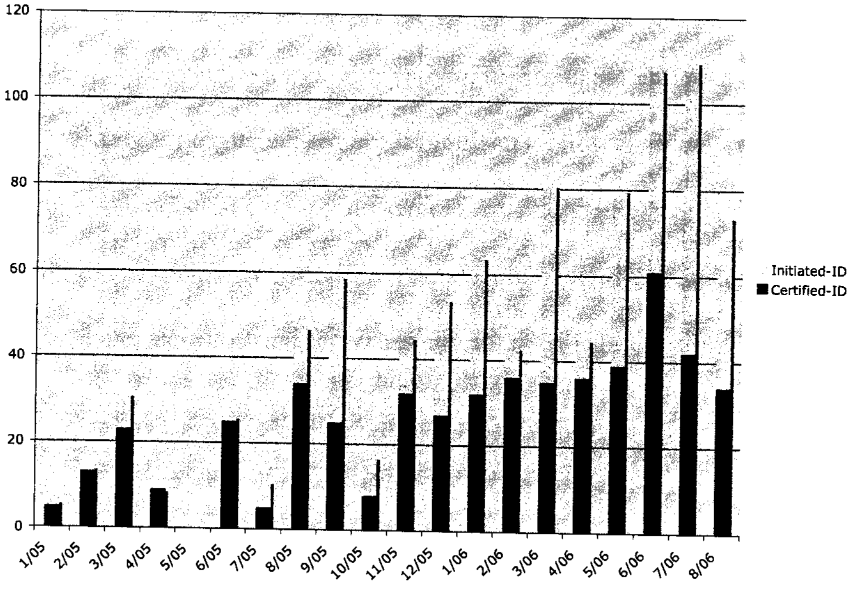


Figure 4: Certified and Initiated Homes by Month - Montana

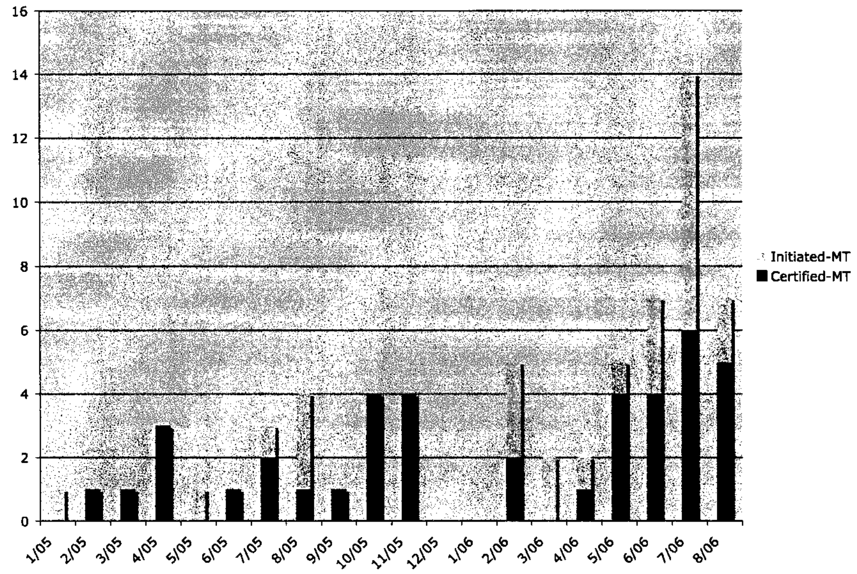


Figure 5: Certified and Initiated Homes by Month - Oregon

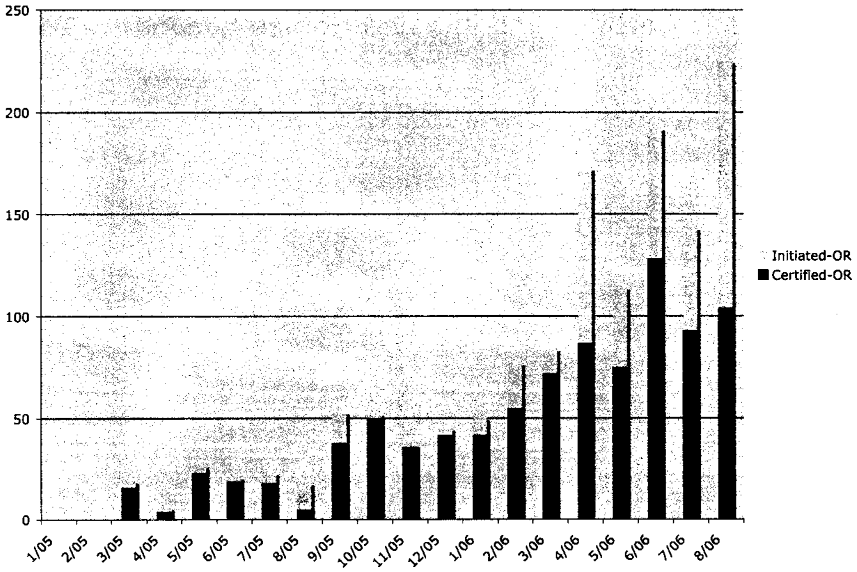


Figure 6:Certified and Initiated Homes by Month - Washington

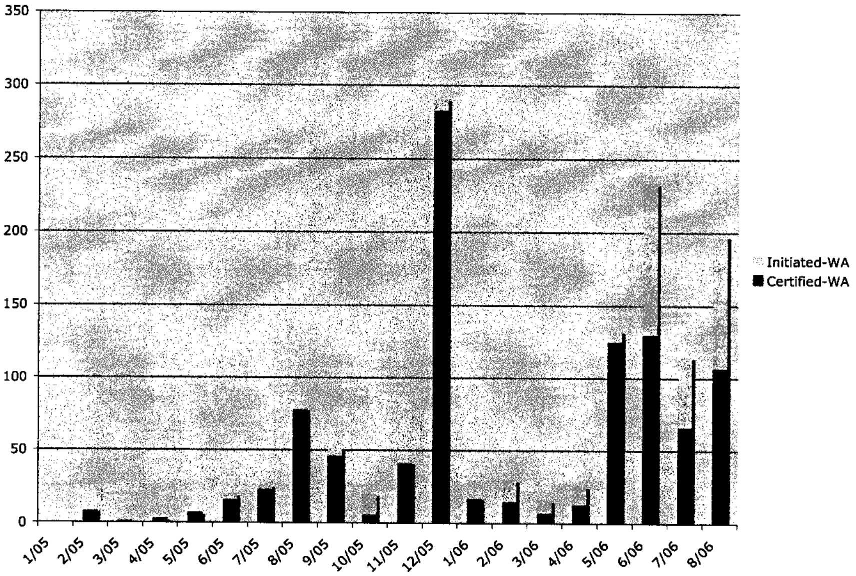
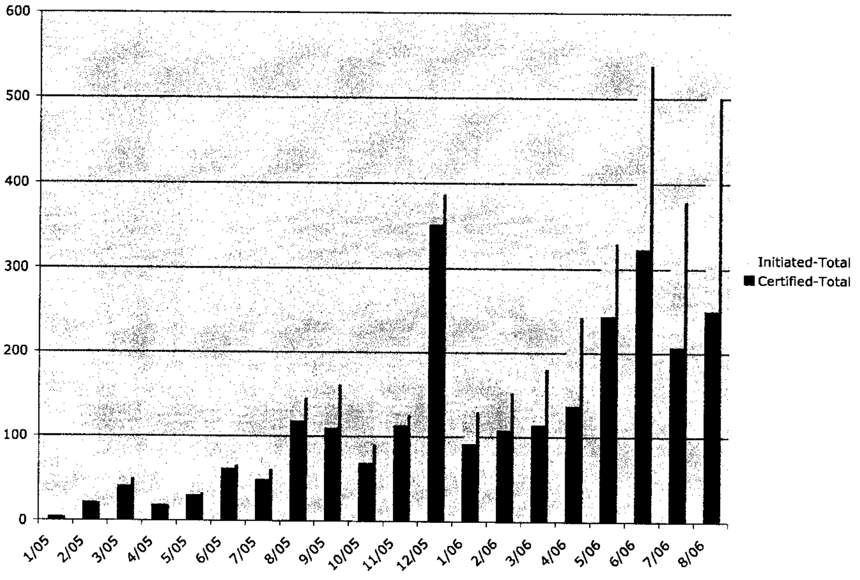
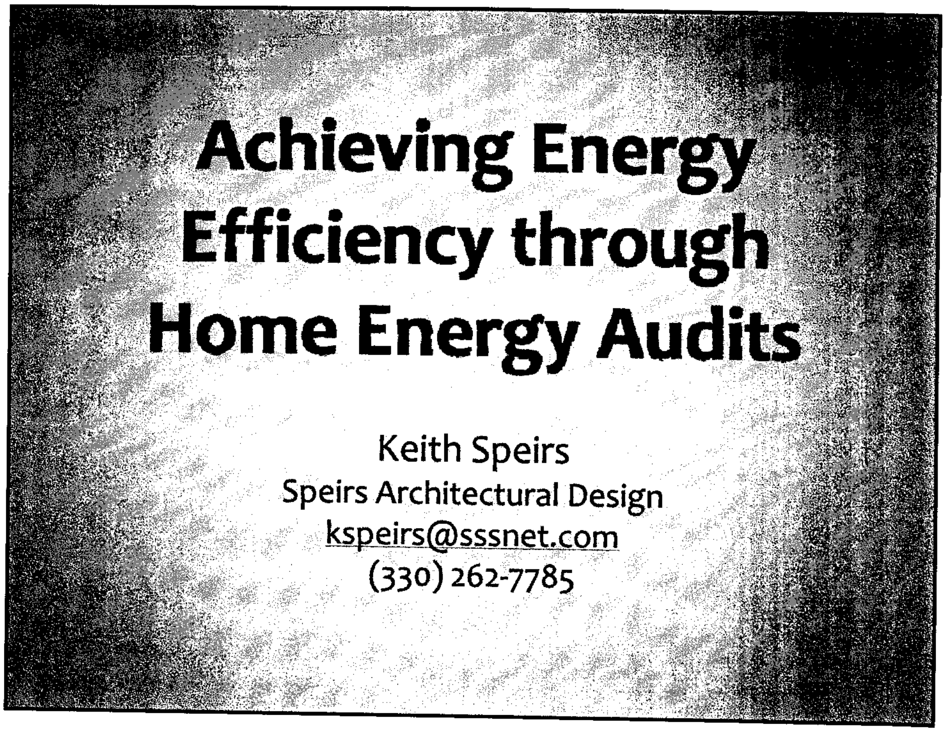


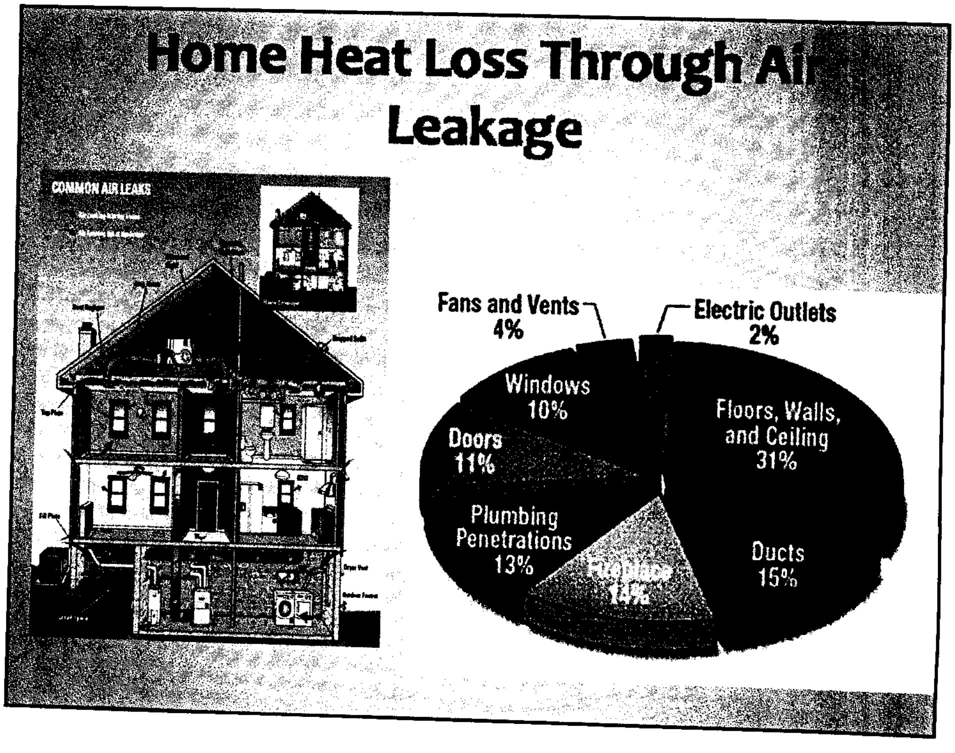
Figure 7: Certified and Initiated Homes by Month - Total



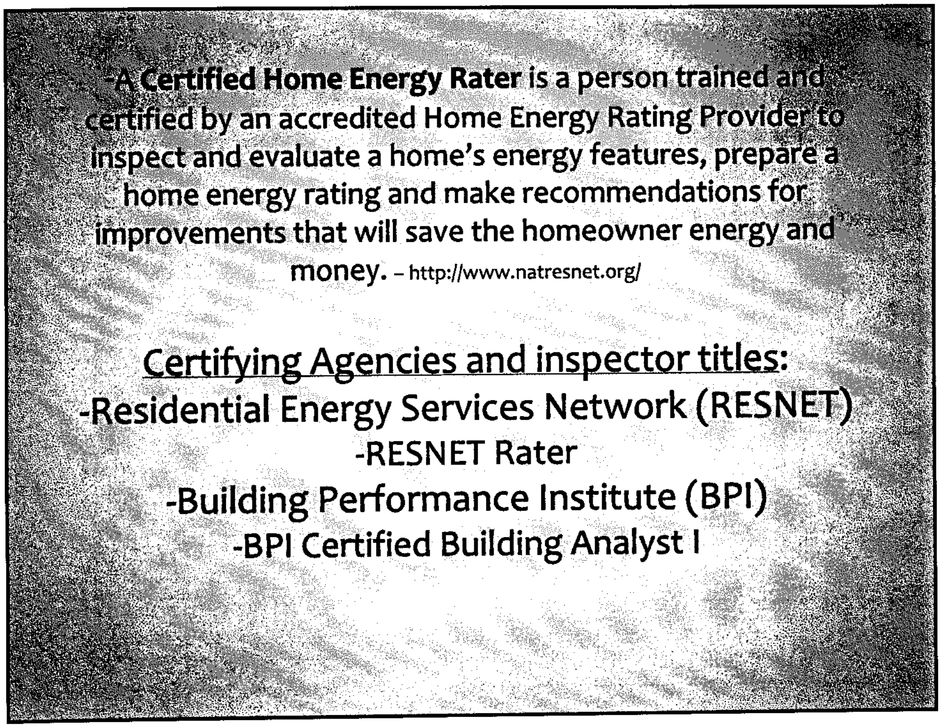


Achieving Energy Efficiency through Home Energy Audits

Keith Speirs
Speirs Architectural Design
kspeirs@sssnet.com
(330) 262-7785



Home Heat Loss Through Air Leakage



-**A Certified Home Energy Rater** is a person trained and certified by an accredited Home Energy Rating Provider to inspect and evaluate a home's energy features, prepare a home energy rating and make recommendations for improvements that will save the homeowner energy and money. – http://www.natresnet.org/

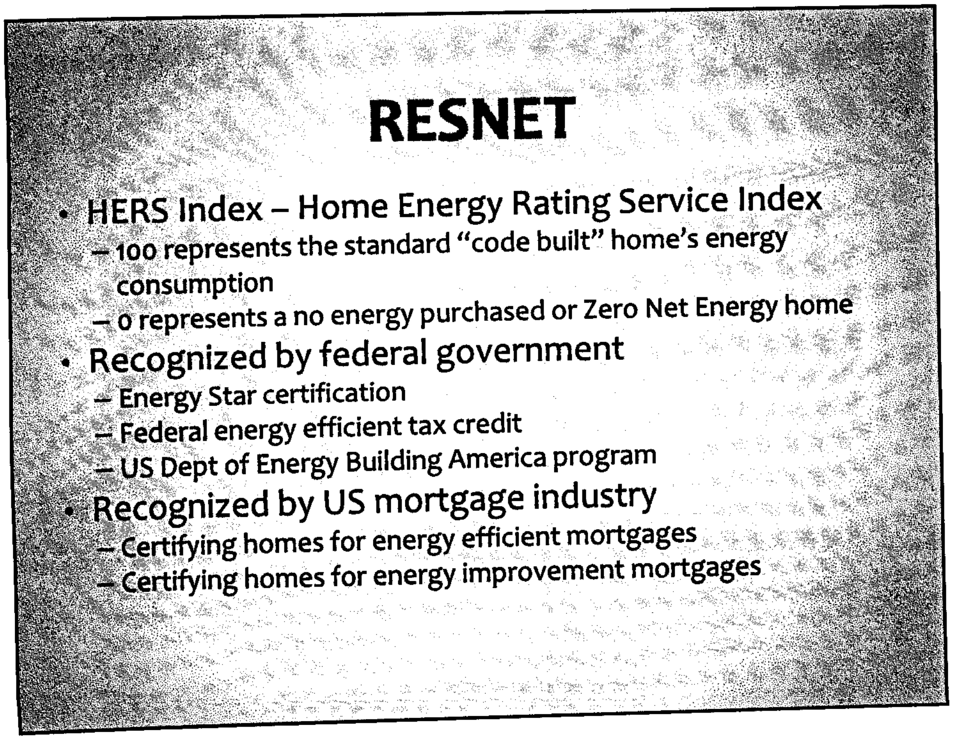
Certifying Agencies and inspector titles:

-Residential Energy Services Network (RESNET)

-RESNET Rater

-Building Performance Institute (BPI)

-BPI Certified Building Analyst I



RESNET

- HERS Index – Home Energy Rating Service Index
  - 100 represents the standard "code built" home's energy consumption
  - 0 represents a no energy purchased or Zero Net Energy home
- Recognized by federal government
  - Energy Star certification
  - Federal energy efficient tax credit
  - US Dept of Energy Building America program
- Recognized by US mortgage industry
  - Certifying homes for energy efficient mortgages
  - Certifying homes for energy improvement mortgages

BPI

- Certifies Building Analysts to be professional energy auditors and weatherization installers
- Working with the federal government on home performance requirements for the Energy Star program

Home Energy Audits

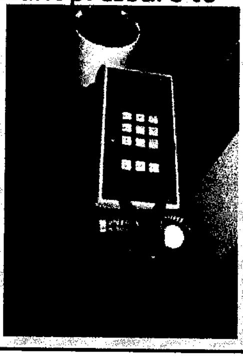
- RESNET Certified Home Energy Audit
  - Used for proposed new construction or existing homes
  - Evaluate envelope of the home for insulation and air leakage
  - Model the home with software to determine heat loss and energy consumption based on design
  - Compare the rated home to a "code built" reference home of the same size and layout to generate a HERS rating
  - Ability to generate best value retrofits and upgrades using Savings to Investment Ratio to determine payback time

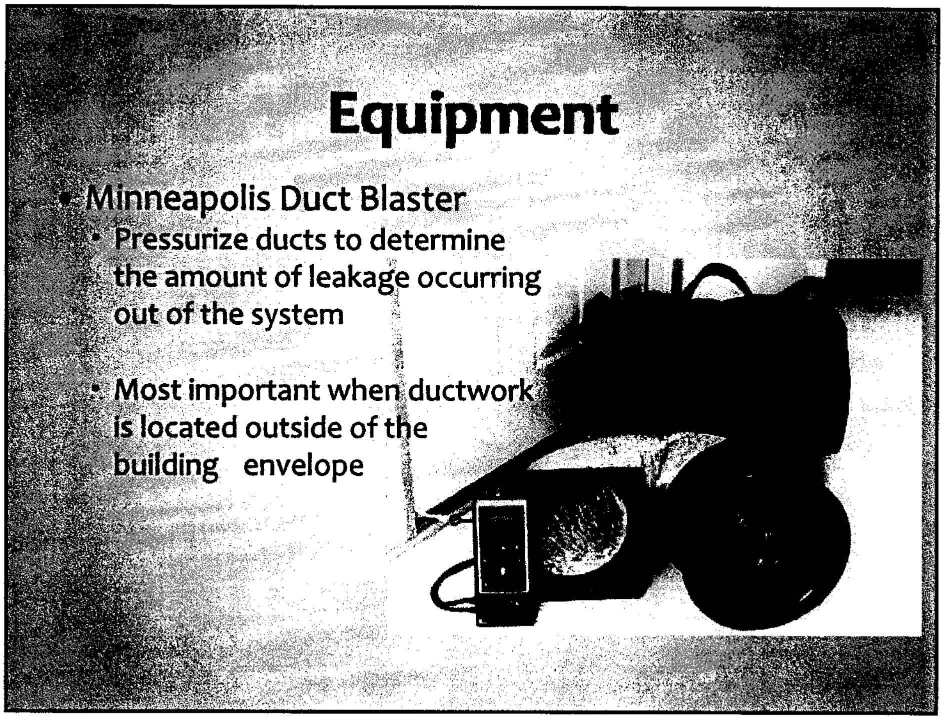
Home Energy Audits

- Air Leakage and Weatherization Audits
  - Multiple packages using multiple tools for home analysis
  - Air leakage is one of the largest contributors to high energy consumption
  - Can contribute to condensation and mold issues
  - Audit determines air leakage into and out of the home in Air Changes per Hour (ACH)
    - American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) specifies minimum safe ventilation and building tightness limits
    - Homes with excessive leakage can be tightened through weatherization practices
  - Audit will locate and identify leakage areas and provide recommendations of how the leaks should be addressed
  - Auditor will generate a report summarizing issues and recommendations along with photos of observations made during the audit

Equipment

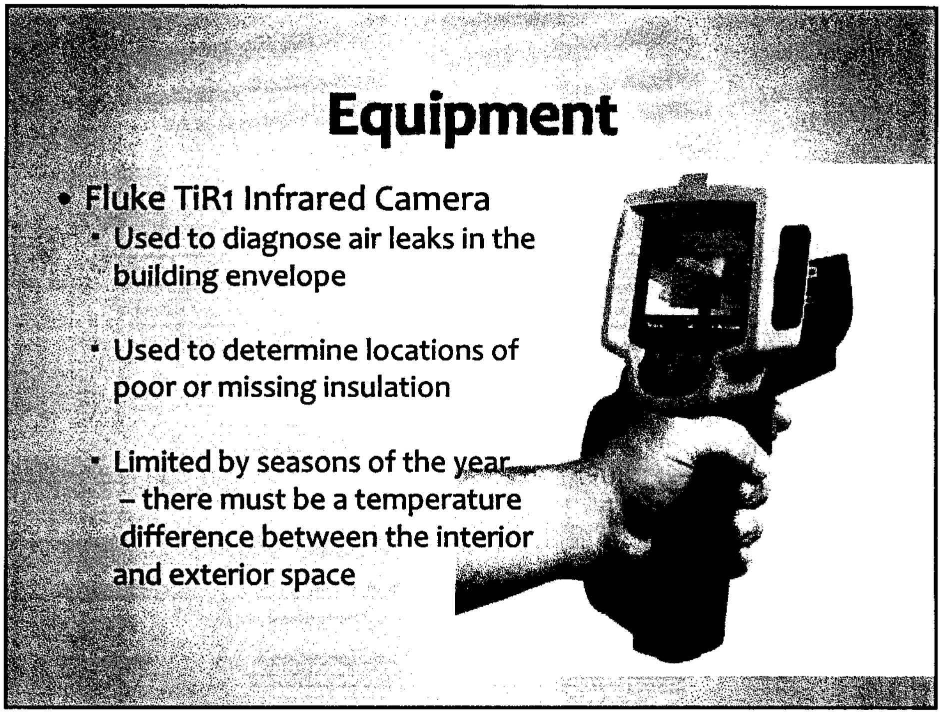
- Minneapolis Blower Door
  - Pressurize or depressurize structure
  - Maintains constant pressure to locate and diagnose leaks





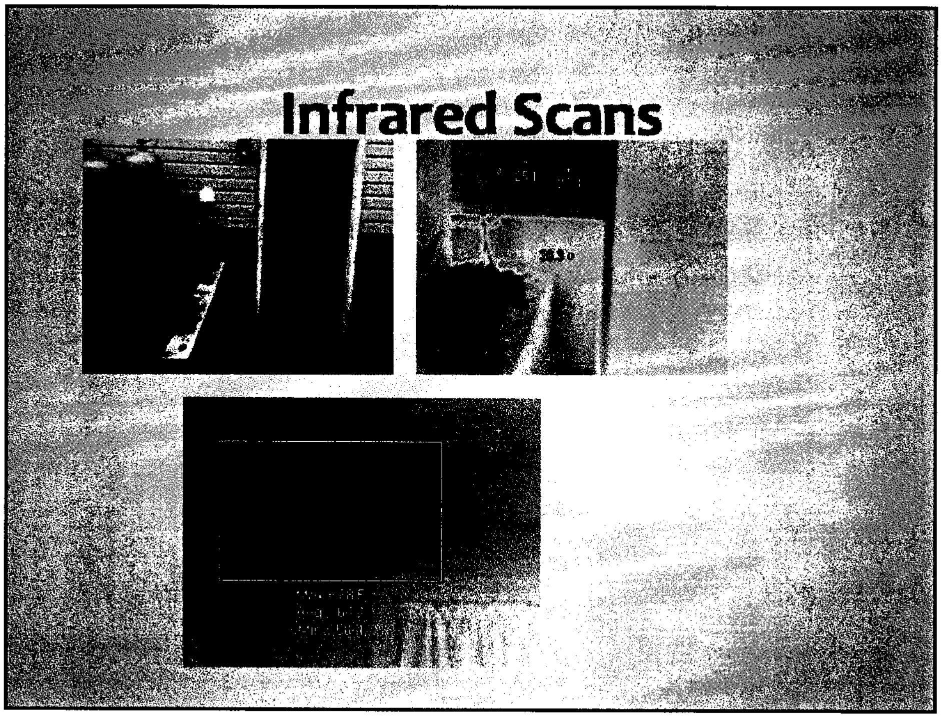
Equipment

- Minneapolis Duct Blaster
  - Pressurize ducts to determine the amount of leakage occurring out of the system
  - Most important when ductwork is located outside of the building envelope

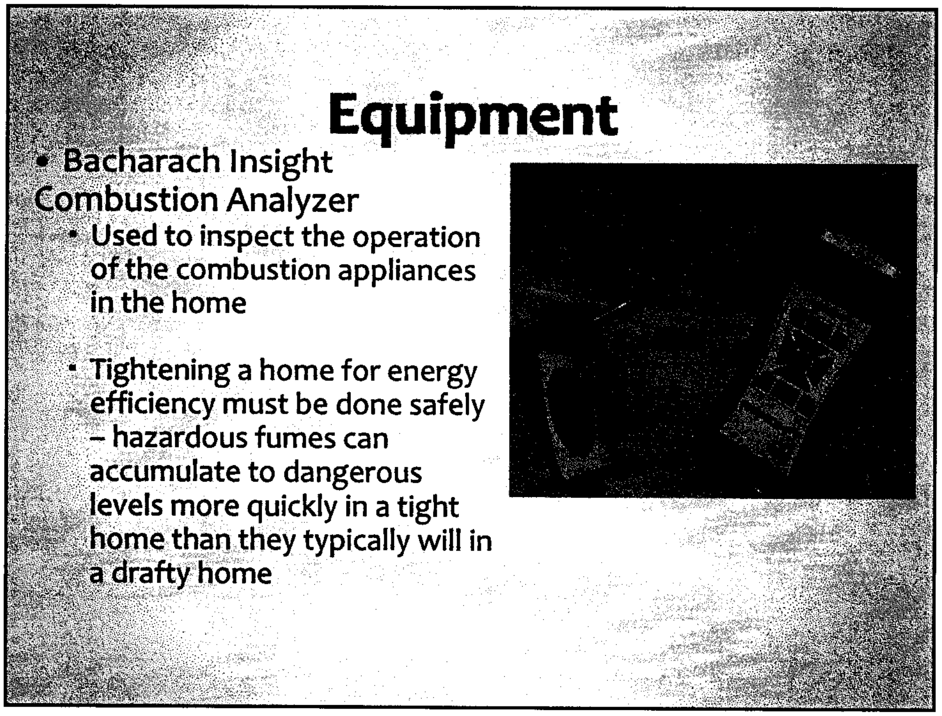


Equipment

- Fluke TiR1 Infrared Camera
  - Used to diagnose air leaks in the building envelope
  - Used to determine locations of poor or missing insulation
  - Limited by seasons of the year – there must be a temperature difference between the interior and exterior space



Infrared Scans



Equipment

- Bacharach Insight Combustion Analyzer
  - Used to inspect the operation of the combustion appliances in the home
  - Tightening a home for energy efficiency must be done safely – hazardous fumes can accumulate to dangerous levels more quickly in a tight home than they typically will in a drafty home

Audit Procedure

- Homeowner Pre Audit Preparation
  - Close and lock all windows
  - Open all interior doors
  - Clean fireplaces completely and close chimney dampers
  - Discontinue use of solid fuel (wood, coal, pellet, corn) combustion devices 12 hours prior to the inspection
  - Make all rooms, basement, and attic entries accessible
  - Make note of any improperly operating doors or windows and note any rooms or locations that are uncomfortable
  - Obtain the past 12 months energy bills, including electric, gas or propane, and fuel oil if applicable

Audit Procedure

- Onsite Energy Auditor Preparation
  - Quick tour of exterior and interior space looking for:
    - Any visible water or leakage issues
    - Verify dampers are closed
    - Turn down or off all combustion devices
    - Removal of one tile from any suspended ceilings if applicable

  - Homeowner interview to determine any areas of particular concern

Audit Procedure

- Energy Audit Procedures & Access
  - Blower door set up in one exterior door
  - Initial IR scan if applicable
  - Operate Blower Door to get leakage information
  - Air infiltration determination with blower door still operating – inspection of all accessible areas
    - Smoke puffer
    - IR camera
  - Worst case draft to verify combustion appliances are receiving proper air for combustion
  - Exclusively for <u>Certified Home Energy Audit</u> package:
    - the Duct Blaster will be set up to pressurize ducts to record data on duct system leakage to the outside of the building envelope
    - Combustion appliance inspection with Combustion Analyzer to check flue gases for proper combustion

Audit Procedure

- Follow up & Report discussion
  - The report will be generated within a few days of the audit
  - The report can be provided electronically or a printed version is available
  - The opportunity can be taken to review the report and contact the Energy Rater with questions

Green and Energy Star Certifcation Testing Options and Requirements

TEST / INDEX	DESCRIPTION	FGBC	NAHB	ENERGY STAR
HERS Index	The HERS (Home Energy Rating System) Index is the energy score for the home. A Home Energy Rater enters specifics from the house into software that calculates the initial HERS Index. A home built to code in our area would have a HERS Index of approximately 85. An Energy Star home is required to have a minimum index of 77. This score changes to a variable HERS Index based on individual home criteria for homes permitted on or after July 1st 2012. The lower the score the better.	Not required, however most projects find it difficult to achieve the minimum points required in the Energy category without it.	Not required but will provide the documentation needed for the Performance Path point number 701.1.1	Required
Ductwork Smoke Test	Performed at rough-in just after completion of duct installation. Installers need to be present. Boots are taped off and theater smoke is blown into the system revealing previously invisible leaks. The installers add additional mastic where needed.	Not required.	Not required but will contribute to point 701.4.2.1	Not required
Thermal Bypass Inspection	A review of the home's insulation looking for incorrectly installed, breached, or missing insulation. Unsealed penetrations or gaps are also indentified.	Not required	Not required but will contribute to points 701.4.3.1 - 701.4.3.4	Required
Duct Blaster Test	Performed at completion to measure duct leakage.	Required if home will be receiving a HERS score. High duct leakage lowers the HERS score. Requesting a smoke test at rough-in will allow the leaks to be repaired ensuring a good Duct Blaster Test score	Required if a HERS score is being used to document compliance with the 701.1.1 Performance Path. Will also contribute to point 701.4.2.1	Required. This is a pass fail test for Energy Star certification. If duct leakage is greater than 6 cfm to outdoors / 100 sq. ft., the home will not receive the Energy Star certification. Requesting a smoke test at rough-in will allow the leaks to be repaired ensuring a good Duct Blaster Test score.

Green and Energy Star Certifcation Testing Options and Requirements

TEST / INDEX	DESCRIPTION	FGBC	NAHB	ENERGY STAR
Blower Door Test	Performed at completion to measure tightness of entire building envelope.	Required if home will be receiving a HERS score	Required if a HERS score is being used to document compliance with the 701.1.1 Performance Path.	Required
HVAC & Ductwork Installation Inspection	Testing and inspections performed at rough in and final to confirm proper installation of the HVAC system.	Not required	Not required	Required
Water Management Inspection	Performed at rough-in and final by the builder and by the HERS rater for any items the builder requests he/she review.	Not required	Not required	Required
OR				**OR**
Indoor airPlus	This certification is offered as an alternative to the Water Management Inspection checklist. The builder and HERS rater are involved in varifying checklist items.			Required

PATH

PARTNERSHIP FOR ADVANCING TECHNOLOGY IN HOUSING

INTERIM REPORT FOR FIELD EVALUATION OF PATH TECHNOLOGIES

SEPTEMBER 2002

THAD FARNHAM HOMES
HAILEY, IDAHO

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1.0 INTRODUCTION

A PATH field evaluation site in Hailey, Idaho is being used to evaluate two non-traditional housing technologies: hydronic radiant heating and an active ventilation system. The approximately 9,400[1] annual heating degree-day load in Hailey makes it an ideal location to do a side by side comparison between a hydronic radiant heating system and a more traditional forced air furnace.[2] This comparison will evaluate energy use (both gas and electric) and total system installation cost.

Indoor air quality, which has long been an issue in the design of ventilation systems for commercial and industrial buildings, is of growing concern to both homeowners and homebuilders. Other than running the bathroom fan, however, many forms of mechanical ventilation systems for the home can be cost prohibitive. This study seeks to evaluate the effectiveness, run time, and energy consumption of an affordable (first and operating costs) mechanical ventilation system for the home – a system that introduces outdoor air to the house based on occupancy levels.[3]

Thad Farnham, a custom home builder based in Ketchum, Idaho with over twenty years of residential construction experience, agreed to open one of his homes for participation in this PATH field evaluation. A 2,642 sq ft, three bedroom, single-family home in Hailey, Idaho was chosen. Construction began in October 2001, and following the site's completion in August 2002, the owners took up residency. Data on the heating and ventilation systems will be gathered through the fall and winter of 2002-2003.

2.0 HEATING SYSTEMS

2.1 System Descriptions

2.1.1 Radiant System Description

The radiant heat system features a gas-fired, stainless steel high efficiency boiler with a 92% efficiency rating (the unit is altitude compensated; its efficiency will not be reduced at the 5,330 foot altitude of the test site). This unit contains a condensing, modulating boiler. Condensing boilers are more efficient than traditional boilers because they use a secondary heat exchanger to capture much of the heat from exhaust gases that are typically vented directly to the outdoors. Modulating boilers are able to vary heat output by changing the volume of gas being burned. Control over flame intensity translates to more precise control over supply water temperature, and consequently, floor temperatures.

---

[1] Ketchum, Idaho, located 12 miles from Hailey has 9,398 HDD as yearly average. Source: NOAA.

[2] Gas furnaces are used in 55% of all United States residences according to EPA's 2001 Residential Energy Consumption Survey.

[3] Mechanical ventilation systems are often run on preset duty cycles versus real time air quality measurements.

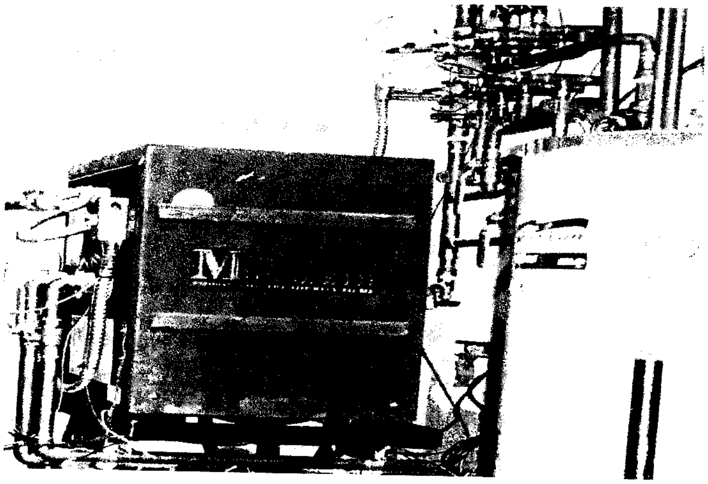

Figure 1 – Munchkin boiler and piping manifold.

Approximately 3,000 feet of 1/2" cross-linked polyethylene (PEX) tubing is used throughout the home. Except for the kitchen/foyer area, the tubing is attached to the underside of the sub-floor with plastic connectors. The kitchen/foyer area features a finished concrete floor with PEX set within the concrete. Fiberglass batt insulation (R-30) is installed under the tubing for the first and second floors to guard against heat loss to the vented crawlspace and overheating of the first floor, respectively.

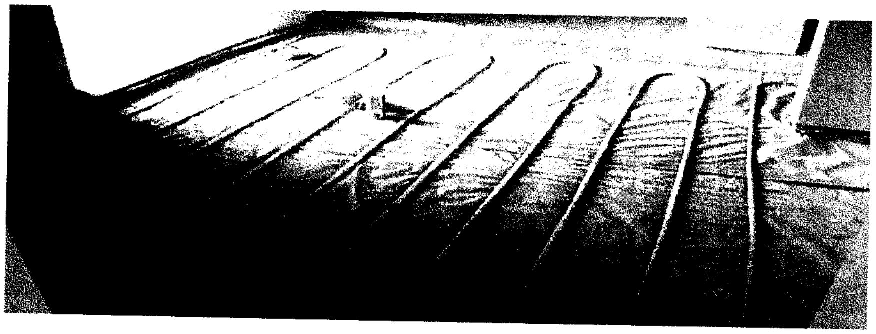

Figure 2 – PEX tubing laid out in foyer before concrete poured.

Plumbing for the hydronic radiant system is routed to the mechanical room located just off the garage where supply and return manifolds are positioned near the boiler. The supply line leaves the boiler and splits into supply lines for the first and second floor. The first and second floor supply lines then split into two zones apiece. Four distinct zones result: first floor north, first floor south, second floor north and second floor south. Because the supply side of these zones' loops are all situated very close to the boiler, it is expected that their input temperatures will be nearly identical. Return temperatures for each zone, however, may vary greatly – as they are dependent upon such factors as flooring thermal conductivity, room temperature, and length of tubing.

Flow through all four zones is provided by a 1/8 HP pump located on the return side of the main loop. Two water flow meters are strategically positioned to allow the determination of flow rates to each zone. Ball valves located on the supply side of each zone can be adjusted to regulate flow through (and consequently, heat to) each zone. Calls for heat are relayed to the radiant system's zone controller through thermostats located on the first and second floors. The zone controller is configured to deliver heat to the first and second floors either individually or simultaneously. In the system's current configuration, a heat call from the first floor thermostat will result in heat delivery to first floor north and south zones, while a heat call from the second floor thermostat will result in heat delivery to second floor north and south zones.

2.1.2 Forced Air System Description

Located next to the boiler within the mechanical room, the forced air system uses a natural gas fired, condensing furnace with a 95.5% efficiency rating. This Energy Star® rated appliance achieves its high efficiency through running the flue gas through a secondary heat exchanger that captures a portion of the exhaust gas heat before it is expelled to the outdoors. Unlike the radiant system, which provides greater user control through a four-zone system, the forced air system has two zones – one for each floor. However, to provide a more parallel comparison between the two heating systems, both the radiant and forced-air systems are configured to operate as two-zone systems.

Controls for the forced air system's zones are provided by thermostats located on the first and second floor. A single-speed central blower is configured to supply heat to both zones in turn, but not simultaneously. For example, suppose both thermostats give a call for heat. Because hot air rises, the furnace system is programmed to supply heat to the first floor before addressing the needs of the second floor. If the second floor thermostat continues to call for heat after the first floor thermostat has reached its set point, an electronically controlled mechanical damper within the first floor supply trunk is closed, while a damper within the second floor supply trunk is opened. In this way, heated air is routed to the second floor.

First floor supply ducts (composed of an uninsulated sheet metal trunk and insulated flex duct branches) drop below the mechanical room and are run through the vented crawlspace. Second floor supply ducts are run upward to the second floor joist system, where they branch out to second story floor register locations. A joist bay is used as the first story return duct, while the second story return duct is routed through the attic.

2.2 Heating System Testing and Monitoring

2.2.1 Testing Method

Both systems will be operated independently for several days to allow the occupants to determine a comfortable operating set point for each. Each system is expected to have comfort points at slightly different operating temperatures. In fact, radiant floor heating systems are often claimed to offer greater comfort at lower set points because of the way in which they warm occupants and their feet. By allowing the occupants to independently determine the point at which each system provides adequate comfort, we hope to gain insight into this claim and also test the energy performance implications for each system.

Following this initial period, each system will run independently for three-week periods. Data from the transition day between periods will be ignored to dampen the effect of thermal mass heat storage. Indoor and outdoor climatic conditions will be monitored to quantify the energy usage required to heat the home under each system.

2.2.2 Data Acquisition

The performance of the radiant heating system will be evaluated through monitoring energy use, heat delivery, house temperatures, and comfort of the residents. To accomplish this objective, data will be collected from temperature sensors, watt-hour meters, and flow meters. Natural gas use will be monitored with the aid of a pulsing gas flow meter that measures natural gas consumption by the boiler. Electricity use will be monitored with a current sensor on the main pump and a watt-hour meter on the boiler's exhaust fan.

Temperatures will be read at various locations throughout the house and the radiant system. Ten submersible thermocouples (TCs) positioned within the radiant system loops will provide supply and return temperatures for each zone (4 zones with 1 TC on supply and 1 TC on return = 8 TCs) and for the main loop (1 TC supply and 1 TC return). Additionally, TCs are located in several areas of the home on the subfloor surface and within the slab to enable monitoring of floor temperatures throughout the home.

Both electric and gas energy used by the furnace system will be quantified. Gas usage will be monitored with a diaphragm gas meter equipped with a pulsing output, and electric energy consumed by the exhaust fan and blower will be tallied with a watt-hour meter. Heat delivered to the house will be calculated from measurements of supply air temperature, return air temperature, and air flowrate. A complete list of data collection points and requisite sensors is located in Appendix A.

2.2.3 Diagnostic Testing

A blower door test performed in August 2002 revealed an ACH50 of 7.6 – that is, the home will experience 7.6 air changes per hour when pressurized to 50 Pascals (Pa). New single-family, detached homes generally register between 6 and 8 ACH50.[4] The duct supply and return performed less favorably – leaking at a rate of 902 cfm when pressurized to 25 Pa by a duct blaster fan.[5] Factors contributing to this high total leakage rate were the large size of the system, the use of loosely sealed sheet metal ducts for many of the runs, and the use of an unsealed joist bay for a section of the return duct.

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[4] This range is based on approximately 100 blower door tests performed by NAHB Research Center technical staff.

[5] Supply and return leakage to both conditioned and unconditioned space.

Figure 3 – Performing the blower door test.

3.0 CO_2 CONTROLLED VENTILATION SYSTEM

3.1 Introduction

CO_2 based ventilation systems have experienced increasing use in commercial HVAC systems (ASHRAE Journal 2001). These control systems use CO_2 as an indicator of occupancy loading conditions in a building, and operate fresh air makeup fans according to monitored CO_2 levels in a zone. In general, CO_2 levels correlate well with human occupancy rates. By using CO_2 concentration in the indoor air as an indicator of building occupancy levels and ventilation requirements, facility managers are able to match the real-time ventilation demands that result from occupant density and activity.

This application saves a great deal of energy compared to introducing a fixed quantity of outdoor air 24 hours a day based on a design maximum occupancy level. By using CO_2 as a control indicator, fan energy consumption is greatly reduced, as is the energy required to condition fresh air brought into the building.

The use of CO_2 systems in residential buildings is far less common than in commercial buildings. For example, a leading CO_2 control manufacturer (Telaire) has provided their controllers to Honeywell for use in their Perfect Climate Comfort Center – a controller that regulates heating and air conditioning equipment, humidity, and ventilation. Other than this application, Telaire was not aware of any significant efforts to use their controllers in residential applications.[6]

An article by Andy Persily of NIST[7] states that CO_2 measurements can be used to indicate the acceptability of a space in terms of human body odor, but they are far less useful as a comprehensive indicator of indoor air quality (IAQ). This is because there is little proven correlation between CO_2 and contaminants that are independent of occupancy rates. However, some IAQ investigators associate indoor CO_2 levels of 600

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[6] Conversation with Mike Schell of Telaire, August 2001

[7] Persily, A.K. "Evaluating Building IAQ and Ventilation with Indoor Carbon Dioxide" ASHRAE Transactions, Vol.103, No.2, 1997.

ppm to 1,000 ppm with perceptions of stuffiness and other indicators of discomfort and irritation.[8,9,10] Persily states that these conclusions are often anecdotal or based on informal surveys of occupants. Studies have shown that 80% of visitors to a space will find the odor to be acceptable when the CO_2 concentration is within 700 ppm of a typical outdoor level of 350 ppm.[11,12,13,14,15,16]

3.2 Operation

Using a CO_2 controller for mechanical ventilation in homes involves the following steps:

- Deciding what threshold level to use as a trigger for the controller to activate ventilation,
- Selecting the fan type(s) to use in conjunction with the controller (i.e. supply, exhaust), where they are located, and how they are ducted,
- Designing the system with proper electronics (interface between the controller and the fan) to operate the system and prevent unintended effects (such as excessive outdoor air migration through the system into a house during off periods),
- Deciding where to locate a CO_2 detector(s) within a building to detect levels in a manner that will have the best impact on indoor air conditions.

3.3 Pros and Cons

Advantages to using a CO_2 based control system for mechanical ventilation in houses include:

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[8] Bright, P.D., M.J. Mader, D.R. Carpenter, and I.Z. Hermon-Cruz. 1992. *Guide for Indoor Air Quality Surveys*. AL-TR-1992-10016. Brooks Air Force Base, Texas: Armstrong Laboratory.

[9] Rajans, G.S. 1983. "Indoor Air Quality and CO_2 Levels". *Occupational Health in Ontario* 4:160-167.

[10] Bell, S.J., and B. Khati. 1983. "Indoor Air Quality in Office Buildings". *Occupational Health in Ontario* 4: 103-113.

[11] Berg-Munch, B., G. Clausen, and P.O. Fanger. 1986. Ventilation requirements for the control of body odor in spaces occupied by women. *Environment International* 12: 195-199.

[12] Cain, W.S., B.P. Leaderer, R. Isseroff, L.G. Berglund, R.J. Huey, E.D. Lipsitt, and D. Perlman. 1983. Ventilation requirements in buildings—I. Control of occupancy odor and tobacco smoke odor. Atmospheric Environment 17(6): 1183-1197.

[13] Iwashita, G., K. Kimura, S. Tanabe, S. Yoshizawa, and K. Ikeda. 1990. Indoor air quality assessment based on human olfactory sensation. *Journal of Architectural Planning and Environmental Engineering* 410: 9-19.

[14] Fanger, P.O. 1988. Introduction of the olf and the decipol units to quantify air pollution perceived by humans indoors and outdoors. *Energy and Buildings* 12: 1-6.

[15] Fanger, P.O., and B. Berg-Munch. 1983. Ventilation requirements for the control of body odor. *Proceedings of an Engineering Foundation Conference on Management of Atmospheres in Tightly Enclosed Spaces*, pp. 45-60. Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

[16] Rasmussen, C., G.H. Clausen, B. Berg-Munch, and P.O. Fanger. 1985. The influence of human activity on ventilation requirements for the control of body odor. *Proceedings of CLIMA 2000 World Congress on Heating, Ventilating, and Air-Conditioning* 4: 357-362.

- Ventilation system operation can be optimized so that fans run only when indoor CO_2 levels reach a user-defined threshold; this feature can reduce daily operating costs relative to continuous or pre-programmed systems.[17]
- During periods of no or low occupancy, this control system will not waste energy by ventilating an empty house.
- Commercially available CO_2 controllers are wall-mountable, attractive, and user friendly.
- CO_2 controller prices have dropped by nearly 50% in the last 3-4 years.

Disadvantages include:

- The foundation of this control strategy is the assumption that CO_2 is a general indicator of IAQ. This may not be the case if significant levels of other indoor air contaminants are present that are independent of occupancy rates (i.e. contaminants that off gas from building products). Consequently, if poor IAQ conditions occur when CO_2 levels are low, this system will not function effectively.
- Monitoring CO_2 levels in one part of the house may not be an adequate indicator of IAQ conditions in other parts of the home; this may necessitate the use of multiple controllers – which would add cost and complexity.

3.4 Ventilation System Description and Installation

The CO_2 controller is affixed to the wall in the family room, four feet above the floor and just around the corner from the kitchen – a highly trafficked air space where CO_2 concentration levels should be higher than in less frequented areas of the home. Telaire's Ventostat 8002 provides a digital display of CO_2 concentration in ppm, a 0 – 10 volt DC output signal, and a relay output rated at 2 amps for 24 volts AC. The threshold for the controller is set to 1,000 ppm. The unit has a default range of 0 – 2,000 ppm, but can be adjusted to have a range as high as 10,000 ppm.

Instead of installing a fan solely dedicated to ventilation, the home's central blower is used to introduce and distribute fresh air from outdoors. This approach reduces the up-front cost of the ventilation system by making use of hardware already in place (central blower and duct runs). Fresh air is introduced to the ductwork via an 8" duct routed directly into the furnace's return plenum. A ventilation system schematic is shown in Figure 4.

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[17] Annual energy costs for the operation of a mechanical ventilation systems' ventilation fan and central blower ranged between $26 and $129 in a study conducted by the NAHB Research Center in 2000. Source: Field Investigation of Mechanical Ventilation Strategies in Residential Construction, Final Report. November, 2001. Prepared by the NAHB Research Center. Prepared for the U.S. Environmental Protection Agency.

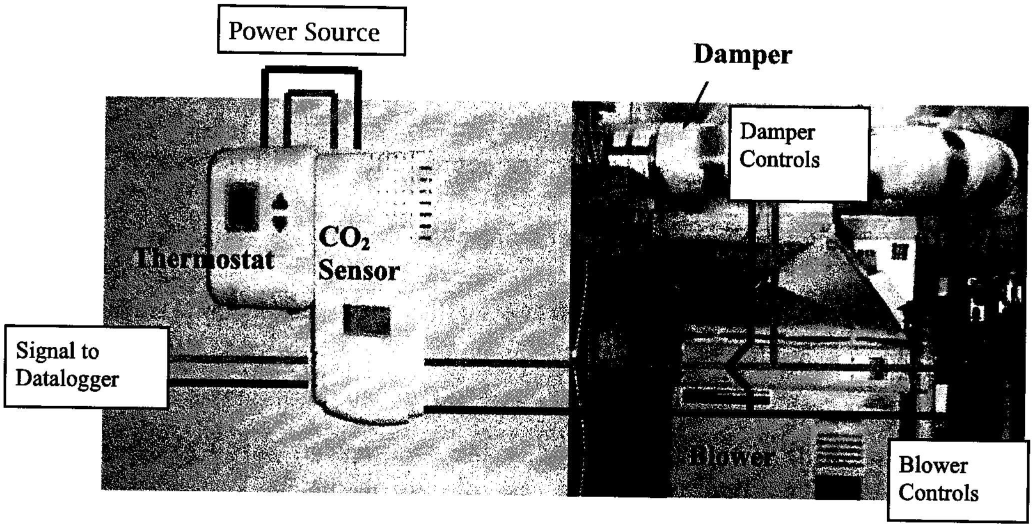

Figure 4 – Wiring schematic of ventilation system. The thermostat (far left) supplies power to the CO_2 sensor (right of thermostat). The CO_2 sensor contains a relay whose normally open connection is wired to the central blower and to a solenoid that controls the outdoor air duct's damper. Green lines represent signal common while red lines represent signal source.

The Ventostat is powered by 24VAC run from the adjacent, first floor thermostat. The Ventostat has relay outputs of normally open and normally closed that are activated when a pre-determined CO_2 threshold is reached. These relay outputs remain activated until a pre-determined lower threshold is reached. At this specific site, the relay's normally open output is wired to the central blower and to a solenoid valve that controls the outdoor air intake damper. When a CO_2 threshold level of 1,000 ppm is reached, the Ventostat's relay sends 24VAC power to the central blower and the outdoor air duct's solenoid valve. Outdoor air is ducted into the house until the lower CO_2 threshold of 950 ppm is reached (at which time the outdoor air duct damper closes and the power supply from the CO_2 sensor to the central blower is disabled).

During the installation and balancing of this system the flow through the outdoor air (OA) duct into the return plenum was measured and fine-tuned. One reason for performing these tasks was to ensure that the temperature in the return plenum does not drop below 60° F when cold, outdoor air is introduced. Due to the possibility of condensation and corrosion within the return plenum at temperatures below this temperature, many furnace manufacturers void warranties if this threshold is breached. By neglecting differences in moisture content of outdoor air and indoor air, the plenum temperature may be calculated using the following simplified formula:

$$\left(\frac{Q_{OA}}{Q_{CB}} \times (T_{HDB})\right) + \left(\frac{Q_{CB} - Q_{OA}}{Q_{CB}} \times (T_{IA})\right) = T_{RP}$$

where

Q_{OA} = Outdoor air flow rate through ventilation duct

Q_{CB} = Air flow rate through the central blower

T_{HDB} = Dry bulb heating design temperature

T_{IA} = Indoor air return temperature

T_{RP} = Return plenum temperature (not to drop below 60° F)

After performing a duct blaster test, the flowrate of the single-speed central blower was determined to be 970 cfm. Taking a dry bulb 99% heating design temperature of -6°F, and assuming an indoor air return temperature of 68°F yields a target outdoor air duct flow rate of 100 cfm. A mechanical damper was then manually adjusted to reduce airflow through the ventilation duct until the target flowrate was reached (flowrate confirmed through testing with duct blaster). This sizing turned out to be more than an academic exercise, because the ventilation duct would have allowed airflow up to 200 cfm when the damper was fully opened. At this flowrate, the return plenum temperature would be below 50°F when the outdoor temperature registered -6°F, and thus would void the furnace warranty.

3.5 Ventilation System Costs

Options for A previous study conducted by the NAHB Research Center found first costs for mechanical ventilation systems to range between \$400 and \$3,200.[18] Systems reviewed in the study included a heat recovery ventilator, energy recovery ventilator, central fan integrated/single port exhaust, multi-port exhaust, multi-port supply, dehumidifying ventilator, and a blending supply ventilator.

A heating recovery ventilator (HRV) is a manufactured unit that provides an energy-efficient way of supplying outdoor air to the home by allowing heat exchange between incoming outdoor air and outgoing indoor air. An HRV may be configured to filter the outdoor air before introducing it to the home. An energy recovery ventilator (ERV) is similar to an HRV, but is able to transfer moisture as well as heat between incoming and outgoing air.

Central fan integrated/single port exhaust (CFI/SPE) systems supply outdoor air to the home with the central HVAC blower. When opened, ductwork connecting the central blower's return plenum with the outdoors allows outdoor air to be drawn into the system during a blower cycle. Indoor air is exhausted to the outdoors through a separate fan and ductwork at some location in the home. The home in Hailey, Idaho uses a central fan integrated system with no exhaust fan, relying on home pressurization and cracks in the building envelope to exhaust indoor air.

A multi-port exhaust (MPE) system has individual units located throughout the home that serve to exhaust indoor air to the outdoors. Exhausting air to the outdoors depressurizes the home and causes outdoor air to be drawn through holes and cracks in the building envelope. Multi-port supply (MPS) systems work in reverse of MPE systems by pressurizing the house through blowing outdoor air into the home and exhausting indoor air through cracks in the building envelope. Dehumidifying ventilators, manufactured units that dehumidify outdoor air before introducing it to the home, may be configured to exchange heat between incoming and outgoing air as well as filter the incoming air.

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[18] Field Investigation of Mechanical Ventilation Strategies in Residential Construction, Final Report. November, 2001. Prepared by the NAHB Research Center. Prepared for the U.S. Environmental Protection Agency.

Material and labor costs required for installation of these mechanical ventilation systems are given in Table 1. Table 2 details the installation cost of the ventilation system used in this field evaluation, a central fan integrated system with no active exhaust, which compares favorably with the installation costs of other systems in the NAHB Research Center's previous evaluation of mechanical ventilation systems.

Table 1 – Mechanical Ventilation Systems' Installation Costs[11]

Mechanical Ventilation System	Installation Cost
Heat Recovery Ventilator	$2200-$2700
Energy Recovery Ventilator	$3155
Central Fan Integrated	$399
Central Fan Integrated/Single Port Exhaust	$700-$930
Multi-Port Exhaust	$1000-$2259
Multi-Port Supply	$679
Dehumidifying Ventilator	$2015

Table 2 – Installed Costs of Mechanical Ventilation System in Hailey, Idaho

Component	Price
Hardware	
Telaire Ventostat 8002 CO_2 Sensor	$265
100' of 2 conductor 20 AWG wire @ $0.15/ft	$15
8" diameter motorized damper	$60
8" diameter damper with manual adjust	$4
Ductwork (7 feet of 8" diameter galvanized run from exterior wall of mechanical room to central blower's return plenum – includes fittings)	$18
Labor	
Controls installation: 1 hour at $50/hour[19]	$50
Ductwork installation: 1.5 hours at $50/hour	$75
Total	$487

3.6 Ventilation System Testing and Monitoring

3.6.1 Testing Method

The CO_2 ventilation system was enabled upon installation and will be monitored through the winter of 2002-2003. Regardless of what home heating system is in use, the ventilation system will be on-call full time. Ventilation system characteristics that will be monitored over the duration of the study include: CO_2 concentration, frequency of ventilation system activation, system run time, and system energy use (including electrical energy use and thermal energy loss due to cold air infiltration in winter).

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[19] Hours are an estimate for an installation scenario involving one heating system, one thermostat, and one CO_2 controller.

3.6.2 Data Acquisition

To collect data on system energy use, CO_2 concentration, and frequency and run time of the ventilation system, a network of sensors has been installed. Home thermal energy loss due to the ventilation system will be calculated from measurements of outdoor temperature, return air plenum temperature, and air flowrate through the outdoor air supply duct (requisite sensors and equipment include thermocouples, a flow sleeve in the outdoor air supply duct, and a pressure transducer connected to the flow sleeve). Electrical energy used by the ventilation system will be quantified by a watt-hour meter on the central blower. A current activated switch positioned on the solenoid controlling the outdoor air duct's damper will be used to monitor damper status (open or closed). Monitoring the outdoor air duct's damper's status will inform as to whether fresh air is being introduced during calls for ventilation. A complete list of data acquisition points and sensors is located in Appendix A.

4.0 LOOKING FORWARD

The heating season in Idaho begins in early fall. Heating system data will be collected and monitored, and modes of analysis will be identified during the first couple months of the heating season. During this time, the occupants will identify comfortable thermostat set points for the radiant and forced air systems. Data on the CO_2 controlled ventilation system is currently being gathered. Data will be disseminated and posted on the web as available.

APPENDIX A

Data Acquisition Table

Parameter	Sensor
First Floor Temperature (Temp)	Vaisala 50Y Humitter
First Floor Relative Humidity	Vaisala 50Y Humitter
Second Floor Temp	Vaisala 50Y Humitter
Second Floor Relative Humidity	Vaisala 50Y Humitter
Outdoor Ambient Air Temp	Vaisala 50Y Humitter
Outdoor Temp (under southeast deck)	Type T Thermocouple
Outdoor Relative Humidity	Vaisala 50Y Humitter
Solar Radiation	LiCor Pyranometer
RS Primary Loop Flow Rate	ABB S130 Hot Water Meter
RS Secondary Loop Flow Rate	ABB S130 Hot Water Meter
RS Primary Loop Pump Status	.5 Amp Current Activated Switch (CAS)
RS First Floor South Supply Loop Temp	Submersible Type T Thermocouple
RS First Floor South Return Loop Temp	Submersible Type T Thermocouple
RS First Floor North Supply Loop Temp	Submersible Type T Thermocouple
RS First Floor North Return Loop Temp	Submersible Type T Thermocouple
RS Second Floor South Supply Loop Temp	Submersible Type T Thermocouple
RS Second Floor South Return Loop Temp	Submersible Type T Thermocouple
RS Second Floor North Supply Loop Temp	Submersible Type T Thermocouple
RS Second Floor North Return Loop Temp	Submersible Type T Thermocouple
Subfloor Temp – Great Room South	Type T Thermocouple
Subfloor Temp – Great Room North	Type T Thermocouple
Subfloor Temp – Kitchen	Type T Thermocouple
Subfloor Temp – Foyer	Type T Thermocouple
Subfloor Temp – Study	Type T Thermocouple
Subfloor Temp – Master Bedroom South	Type T Thermocouple
Subfloor Temp – Master Bedroom North	Type T Thermocouple
Subfloor Temp – Bedroom 3	Type T Thermocouple
Supply Air Plenum Temp (2' down Supply Trunk)	Type T Thermocouple
Supply Air Plenum Temp (20' down Supply Trunk)	Type T Thermocouple
Return Air Plenum Temp	Type T Thermocouple
Central Blower Status	Current Sensor
Central Blower Energy Use	Watt-hour meter
Furnace Gas Valve Status	24VAC Relay
Boiler Gas Valve Status	24VAC Relay
Boiler and Furnace Gas Use	Diaphragm Gas Meter with pulsing output (1 pulse per ¼ cubic foot)
Outdoor (Ventilation) Air Flow	8" Flow Sleeve in ventilation duct w/ pressure transducer
Outdoor Air Duct Damper Status	.5A Current Activated Switch
Carbon Dioxide Concentration	Ventostat 8002
Boiler Electrical Energy Use	Watt-hour meter

Nomenclature: RS = Radiant System, Temp = Temperature

REGIONAL TECHNICAL FORUM

Revised June 6, 2006 ©

Performance Tested Comfort Systems® Duct Program Standards and Testing Procedures

1. **Performance Tested Comfort System (PTCS) Duct Program Standards**
2. **Required Testing Procedures**
3. **Other Useful Diagnostic Procedures**
4. **Sample Labels & Reporting Forms**

Duct System Diagnostic Procedures

Testing Protocols

The required procedures for performing the following tests are contained in this manual.

1. **Total Duct Leakage Test**
2. **Duct Leakage to the Exterior Test**
3. **Combustion Appliance Zone Pressure Test**

Certification of a duct system under the PTCS program requires that one or more of these tests are performed on each system. A certified technician to complete the certification process must provide documentation to the sponsoring utility or the Energy Star Program of the test results showing compliance with **Performance Tested Comfort System (PTCS)** Duct Program standards.

The table (below) shows under which circumstances each test is required.

In existing homes, testing is required both before and after sealing. Existing homes that meet program standards without additional sealing may be certified. A home must be occupied for a least one year before it is eligible to be certified under the existing home standards. Check with sponsoring utilities for availability of and eligibility for incentive payments.

Type of Home	Required Tests				
	(1) Total Leakage		(2) Leakage to Exterior		(3) Combustion Zone
New Home	**X**	**or**	**X**		
with combustion	**X**	**or**	**X**	**and**	**X**
Existing Home			**X**		
with combustion			**X**	**and**	**X**

Duct Sealing: Performance Tested Comfort System (PTCS) Program Standards

New Construction: Based on the protocol for "Total Leakage Testing", or "Leakage Testing to Exterior" duct leakage in new construction shall not exceed 0.06 CFM50 x floor area served by the system (in square feet), or 75 CFM50 whichever is greater.

> Exception 1: if the air handler is located completely within conditioned space, it is not required to be in place during the test.
>
> Exception 2: If the air handler is located in unconditioned space, it is not required to be in place during the test, the leakage limit shall be decreased to 0.04 x floor area served by the system (in square feet) or 50 CFM50, whichever is greater.)

In addition the following requirements must be met:

1. All *testing* must be done by a PTCS Certified Technician or Inspector;
2. Duct systems must be designed, sized and installed using recognized industry standards so that calculated heating and/or cooling loads are delivered to each zone (documentation may be required);
3. Based on the protocol for "Combustion Appliance Zone Pressure Testing" forced air system operation shall not de-pressurize a combustion appliance zone by more than 3 Pascals.
4. When combustion appliances are located within a conditioned space a UL listed carbon monoxide alarm, or equivalent must be installed.

Sealing Materials: All duct sealing shall be done with mastics that meet the UL-181 AM or BM standard. Where taping is necessary (to provide service access), only UL-181 listed tape shall be used. Cloth duct tape is not acceptable.

Performance Tested Comfort System (PTCS) Program Standards

Existing Home, New Ducts: Based on the protocol for "Total Leakage Testing", or "Leakage Testing to Exterior" duct leakage for new systems in existing homes shall not exceed 0.10 CFM50 x floor area served by the system (in square feet), or 75 CFM50, whichever is greater.

In addition the following requirements must be met:

1. All testing must be done by a PTCS Certified Technician or Inspector;
2. Duct systems must be designed, sized and installed using recognized industry standards so that calculated heating and/or cooling loads are delivered to each zone (documentation may be required);
3. Based on the protocol for "Combustion Appliance Zone Pressure Testing" forced air system operation shall not depressurize a combustion appliance zone by more than 3 Pascals.
4. When combustion appliances are located within a conditioned space a UL listed carbon monoxide alarm, or equivalent, must be installed.

Sealing Materials: All duct sealing shall be done with mastics that meet the UL-181 AM or BM standard. Where taping is necessary (to provide service access), only UL-181 listed tape shall be used. Cloth duct tape is not acceptable.

Performance Tested Comfort System (PTCS) Program Standards

Existing Homes, Existing Ducts: Based on the protocol for testing "Duct Leakage to the Exterior", duct leakage in a retrofitted system shall:

A) Not exceed 0.10 CFM50 x floor area (in square feet) served by the system;

Or

B) Document a 50% reduction* in leakage to the outside by comparing duct leakage to the outside before and after sealing;

Or

C) In extreme cases where return ducts are inaccessible, compliance with either A or B may be accomplished by testing the supply side only.

Regardless of qualifying path, all accessible components of the supply plenum and all accessible take offs including the gores on flexible elbows shall be sealed with approved materials. In addition the following requirements must be met:

1. All testing must be done by a PTCS Certified Technician or Inspector:
2. Based on the protocol for "Combustion Appliance Zone Pressure Testing" forced air system operation shall not de-pressurize a combustion appliance zone by more than 3 Pascals.
3. When combustion appliances are located within a conditioned space a UL listed carbon monoxide alarm, or equivalent must be installed.

*The leakage rate specified in A and B above is required for an existing system to be certified as meeting the PTCS standard. Some utilities may pay an incentive for "test only" (for less than a 50% reduction or greater than 10% of floor area). Contact the sponsoring utility for specific program details.

Sealing Materials: All duct sealing shall be done with mastics that meet the UL-181 AM or BM standard. Where taping is necessary (to

Performance Tested Comfort System (PTCS) Program Standards

For Manufactured homes: Based on the protocol for "Total Leakage Testing", or "Leakage Testing to Exterior" duct leakage in manufactured homes shall document a 50% reduction* in leakage to the outside by comparing duct leakage to the outside before and after sealing.

In addition the following requirements must be met:

1. Be conducted by a PTCS Certified Technician or Inspector
2. Have an existing tested leakage rate of 100 CFM50 for single wide homes or 150 CFM50 leakage for two or more section homes
3. Based on the protocol for "Combustion Appliance Zone Pressure Testing" forced air system operation shall not de-pressurize a combustion appliance zone by more than 3 Pascals.
4. When combustion appliances are located within a conditioned space a UL listed carbon monoxide alarm, or equivalent must be installed.

*Some utilities or system benefits administrators may pay an incentive for "test only" or less than a 50% reduction. Contact the sponsoring utility for specific program details.

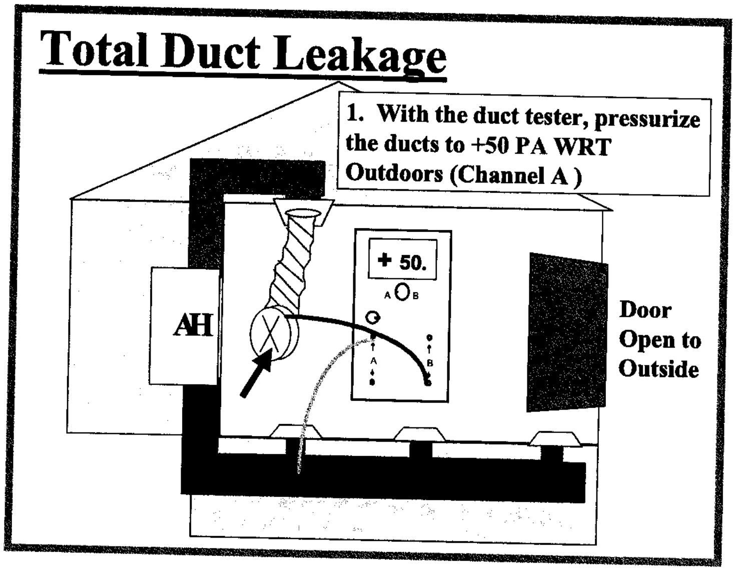
Sealing Materials: All duct sealing shall be done with mastics that meet the UL-181 AM or BM standard. Where taping is necessary (to provide service access), only UL-181 listed tape shall be used. Cloth duct tape is not acceptable.

Total Duct Leakage Test

Testing Procedure

Application: For the PTCS Program perform this test **only on new homes**. This test is most appropriate in new construction when ducts are to be tested at the rough-in stage before the house envelope is intact. The test measures the CFM50 value of the duct system. It is a simpler test, but a more stringent standard than the leakage to exterior test that may be used as an alternative.

Standard: For certification, the measured CFM50 must not exceed 0.06 CFM50 x floor area served by the system (in square feet) or 75 CFM50 whichever is greater.



Total Duct Leakage

1. With the duct tester, pressurize the ducts to +50 PA WRT Outdoors (Channel A)

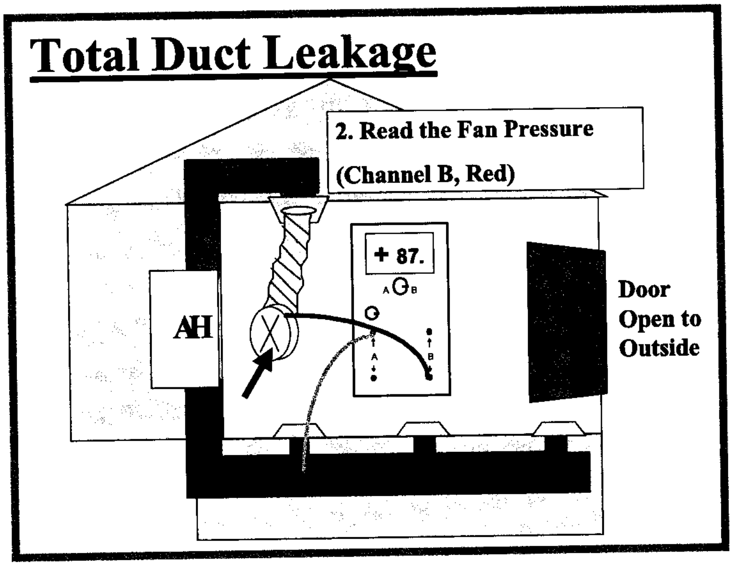
Tools and Equipment:

- Duct tester
- Manometer
- Tape and paper or duct mask to seal registers

Setup:

- Remove air filters from the air handler.
- Open all duct dampers (Note setting and return after testing).
- Attach the duct tester to the return register closest to the air handler. **or**
- Attach the duct tester to the air handler cabinet (Preferred location).
- Place the duct pressure tube in the supply register closest to the air handler. **or**
- Place the duct pressure tube in the supply plenum.

- Seal all the duct system supply and return registers with tape, paper, or mask.
- Open an exterior door or window so that all spaces exterior to the ducts are at outside pressure.



Total Duct Leakage

Test:

1. With the Duct Tester **pressurize** the ducts to **+50 Pa WRT to outside**.
2. Read the fan pressure and follow your Duct Tester instructions to determine the **CFM50** leakage of the system. If you can't reach +50 Pa, perform the test at the highest attainable pressure (rounded to the nearest 5 Pa) and correct the results (see interpreting results below).

Interpreting Results:

The **CFM50** is a measure of the total collected hole size in the system. As an approximation the CFM50 divided by 10 gives the total effective leakage area in square inches.

Example: 400 CFM50/10 = 40 square inches of total leakage area.

Using this approximation during sealing can help estimate how many and how big the holes are that you are looking to seal.

If you could not perform the test at +50 Pa adjust your results using Table 1 (see page 33).

Example: The results of the test show a leakage area of 275 CFM at a duct pressure of 35 Pa. The correction factor from Table 1 for a pressure of 35 Pa is 1.26.

275 CFM35 X 1.26 = 346.5 CFM50

The test doesn't give any indication of where to find the holes, just an estimate of the collected hole size. As CFM50 values get larger, they will tend to be less accurate. In the range of values required for certification, the test should be most accurate.

Limitations: Inaccuracies are introduced because the test assumes a constant pressure difference from inside to outside the ducts throughout the system during testing. This is not always true because of pressure drops caused by large holes and possible induced pressures in buffer zones. Because the assumed constant pressure difference doesn't accurately model the dynamic pressure gradient present during normal system operation, the test measured hole size does not always correlate well with heat loss and potential savings. The assumption, however, is that in new construction, the tighter, the better.

Duct Leakage to the Exterior

Testing Procedure

Application: This test may be used on either **new or existing homes.** In new construction, doors and windows must be installed and the building envelope capable of maintaining +50 Pa WRT outside pressure with the operation of a blower door. By pressurizing the interior of the home with a blower door while using a duct tester, duct leakage to the interior is eliminated from the measurement. The test attempts to measure the CFM50 value for holes in the duct system outside of conditioned space. In **existing homes**, by performing a pre and post test documenting a 50% reduction in leakage area, it is sometimes possible to certify homes that otherwise would not qualify.

Standard:

New Construction: For certification, the measured CFM50 must not exceed 0.06 CFM50 x floor area served by the system (in square feet) or 75 CFM50 whichever is greater.

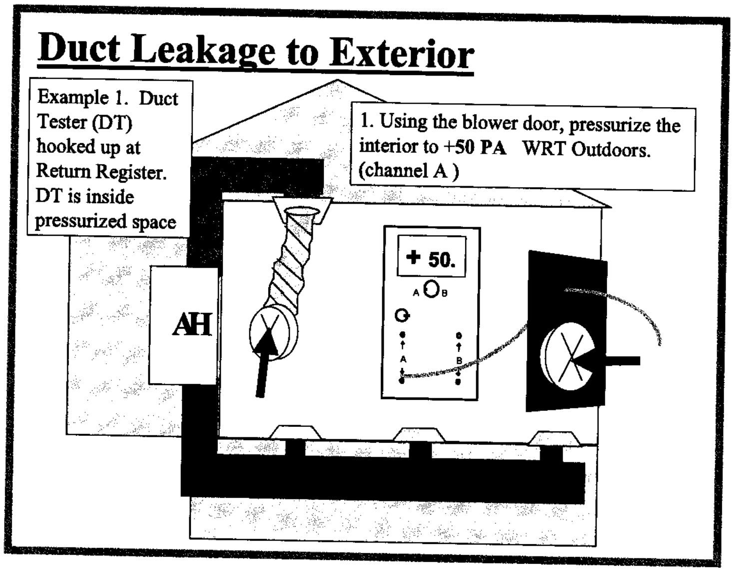
Existing Homes: For certification, the measured CFM50 must not exceed 0.10 CFM50 x floor area (in square feet) served by the system;

Or

Document a **50% *reduction**** in leakage to the outside by comparing duct leakage to the outside before and after sealing.

*The leakage rate specified above or a minimum 50% reduction in duct leakage is required for an existing system to be **certified** as meeting the PTCS standard. Some utilities may pay an incentive for "test only" or less than a 50% reduction. Contact Climate Crafters or the sponsoring utilities for specific program details.

Tools and Equipment:

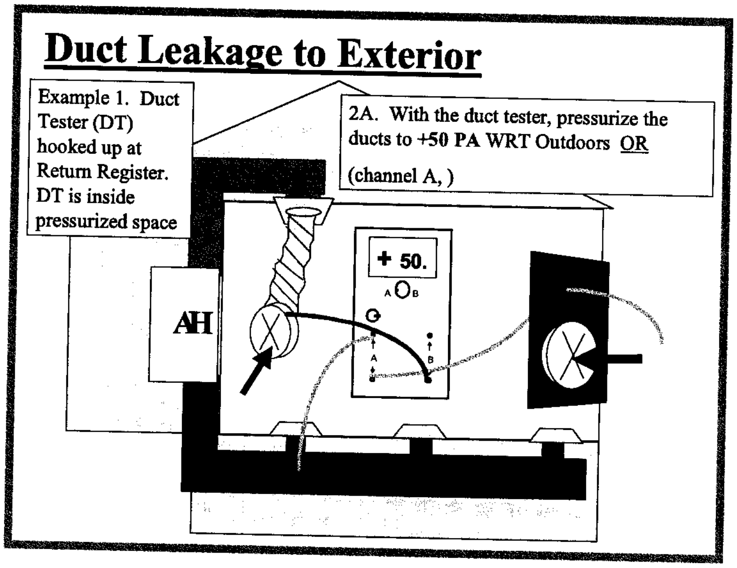


- Blower Door
- Duct Tester
- Manometer
- Tape and paper or duct mask to seal registers

Setup:

Example 1. Duct Tester is hooked up at largest return register. The duct tester is inside the pressurized zone of the house when the blower door is turned on.

- Prepare house for a standard blower door test.
- Set up **blower door** and set to pressurize the house.



- Set up the **Duct Tester** as in a total leakage test except all exterior doors and windows must be closed.

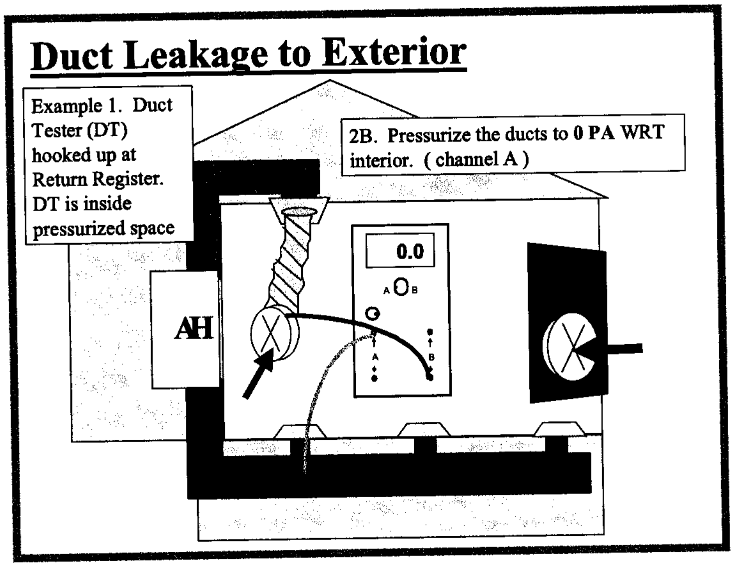
Test:

1. Using the **blower door** pressurize the interior to **+50 PA WRT outdoors.**

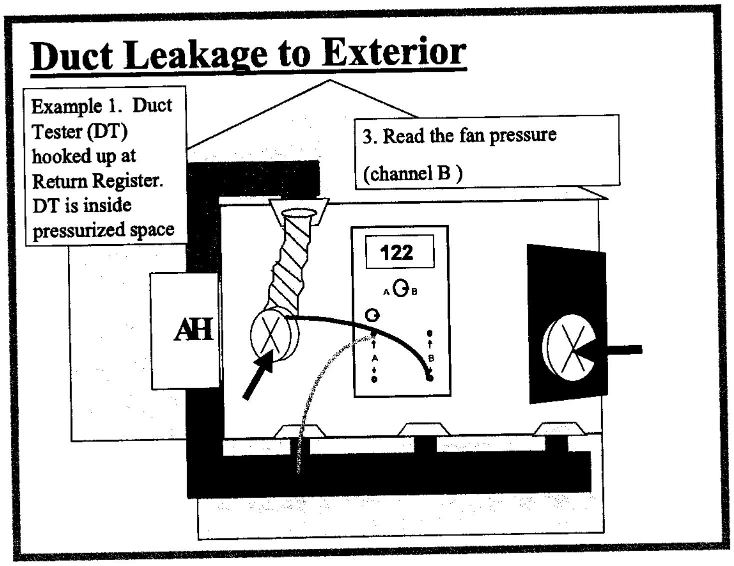
2A. With the **Duct Tester**, pressurize the ducts to + **50PA WRT outdoors**.

Or

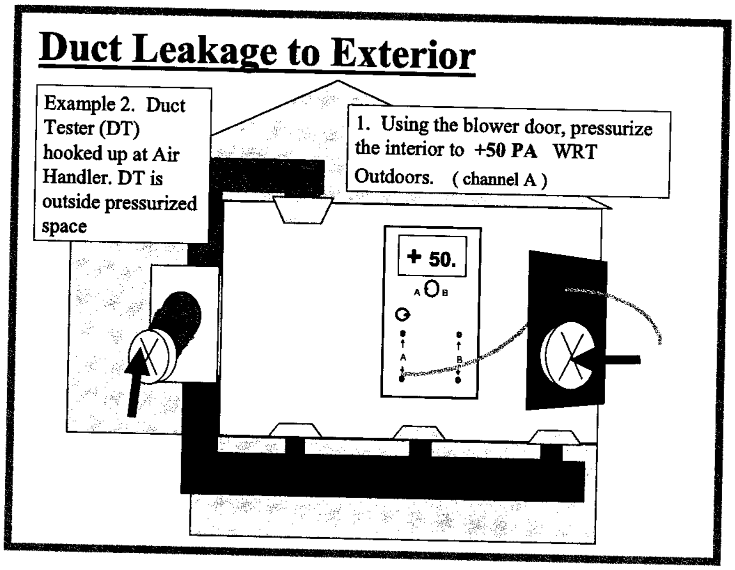
2B. With the **Duct Tester**, pressurize the ducts to **0 PA WRT interior**



Check the blower door reading to assure it is still at +50PA.



3. Measure Fan Pressure of the Duct Tester. **Note**: You may need to adjust the ring size of the duct tester (see duct tester manual).
4. Convert Fan Pressure to CFM50 measurement by consulting the duct tester manual.

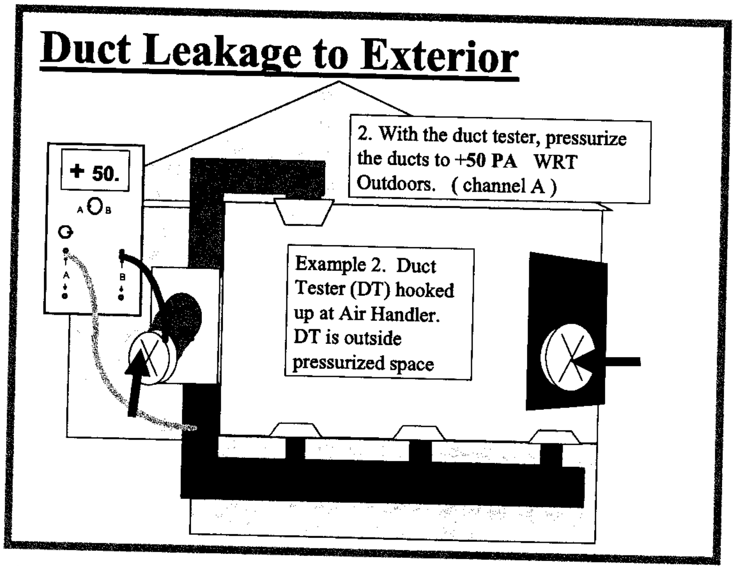

Duct Leakage to Exterior

Example 2. Duct Tester (DT) hooked up at Air Handler. DT is outside pressurized space

1. Using the blower door, pressurize the interior to **+50 PA** WRT Outdoors. (channel A)

Example 2. Duct Tester is hooked up at Air Handler. Depending on the location of the Air Handler, the Duct Tester may be either inside or outside the pressurized zone of the house. (Outside in pictured example)

Follow the same steps as in Example 1.

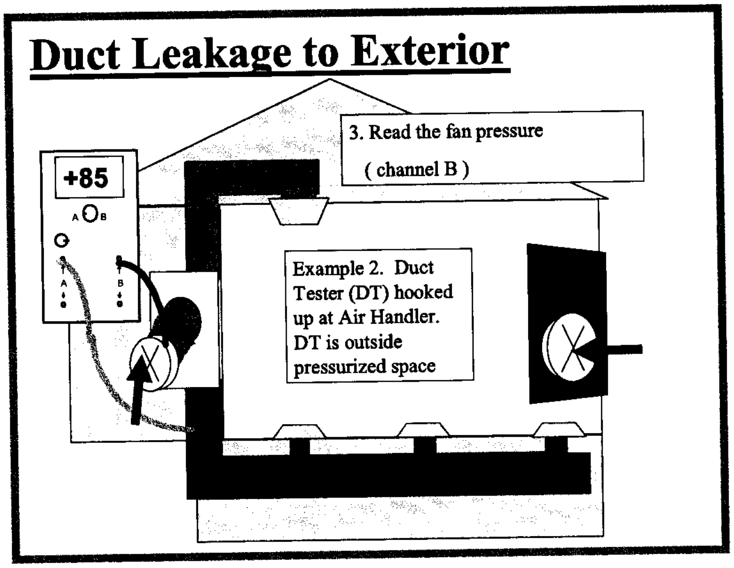

Duct Leakage to Exterior

2. With the duct tester, pressurize the ducts to +**50 PA** WRT Outdoors. (channel A)

Example 2. Duct Tester (DT) hooked up at Air Handler. DT is outside pressurized space

Note:
In this example because the Duct Tester is outside of the pressurized zone of the house, it is no longer necessary to run a pressure hose from the reference pressure tap on channel A to the outside when determining the duct pressure WRT to outside as it was in Example 1.

In any case, if either the house or the ducts can't be pressurized to 50 Pa WRT to outside, pressurize them both to highest same value possible (rounded to the nearest 5 Pa) and then convert to CFM50 using Table 1 (see page 33).



Interpreting Results:

By pressurizing the house to the same pressure as the ducts, holes between the ducts and the house are assumed to have no pressure difference and therefore make no contribution to the measured CFM50. All the measured leakage is to the exterior. Generally this will be a more reliable indicator of potential energy savings than a *Total Leakage* test.

The test doesn't give any indication of where to find the holes, just an estimate of the collected hole size to the outside. As CFM50 values get larger, they will tend to be less accurate. In the range of values required for certification, the test should be most accurate. Documenting a 50% reduction of a very leaky system for certification may not provide the desired benefits. Always try to get the systems as tight as possible.

Limitations: The test assumes that the pressures inside the ducts and outside the ducts within the house are always equal during the test. This is not always true and may skew the results. Two story houses with ducts in the second story floor cavity and houses with ducts in other buffer zones that are partially pressurized by the blower door may produce unreliable results.

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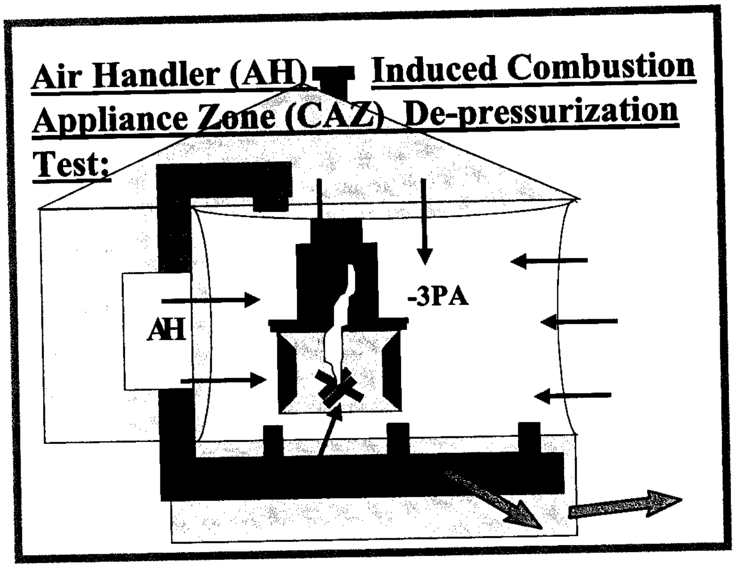
Combustion Appliance Zone Pressure Test

Testing Procedure

Application: This test is required for PTCS Certification whenever a combustion appliance is present within a building. A **Combustion Appliance Zone (CAZ)** is any zone in the house that contains a combustion appliance. CAZs need not be heated. An attached garage or unheated basement with a combustion-fired furnace or water heater **is** a CAZ. A zone with a **sealed combustion appliance** that has an isolated combustion path preventing mixing of room air and combustion air **is not** considered a CAZ. The test measures the magnitude of any air handler induced pressure effects within the combustion appliance zone. Supply leaks to the exterior and return leaks within a zone create negative pressures that may cause dangerous back drafting of combustion appliances. Door closer that isolates supply and return sides of the system may also induce negative pressure within a combustion appliance zone. In **retrofit** situations, the test should be done both before and after sealing. **Note:** This test only measures air handler induced effects and is not a worst-case test.

Standard: Forced air system operation shall not de-pressurize a combustion appliance zone by more than 3 Pascals with reference to outside. As a further safety precaution, the Climate Crafters Standard also requires the installation of a UL listed Carbon Monoxide whenever combustion appliances are within the conditioned space of the home.



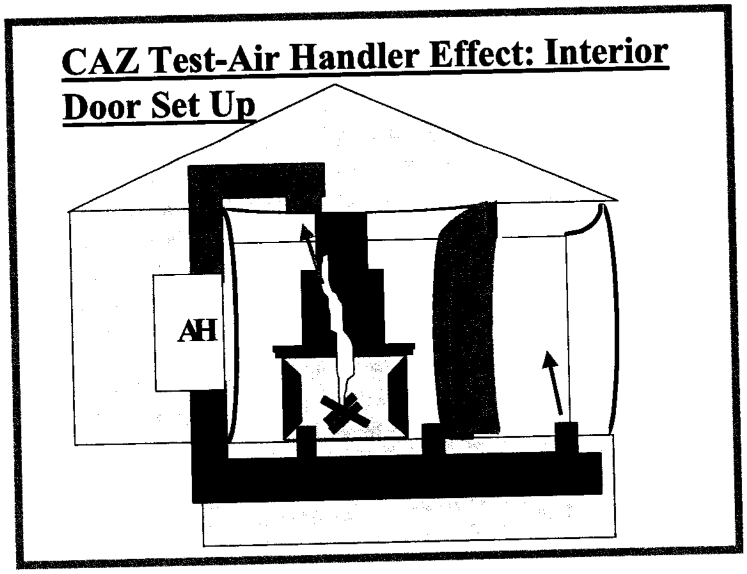
Air Handler (AH) Induced Combustion Appliance Zone (CAZ) De-pressurization Test;

Tools:

- Micro-manometer

Set Up:

- The house should be set up for normal heating season operation with all **exterior doors and windows closed**.
- **Turn off all exhaust devices** including clothes dryer, bathroom fans, kitchen fan, central vacuum, and whole house ventilation systems.
- **Open** all return and supply **registers.**
- **Turn off combustion devices** so that they will not operate during the test (except furnace if air handler will not operate at high speed without firing).
- **Remove** furnace **filters.**
- **Shut** off any **outside ventilation air** to the duct system if it can normally be shut off during air handler operation.
- **Close manual flue dampers**

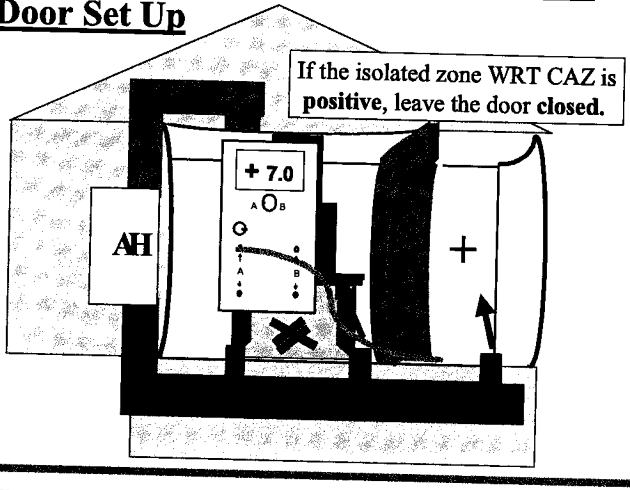


CAZ Test-Air Handler Effect: Interior Door Set Up

Door Set Up:

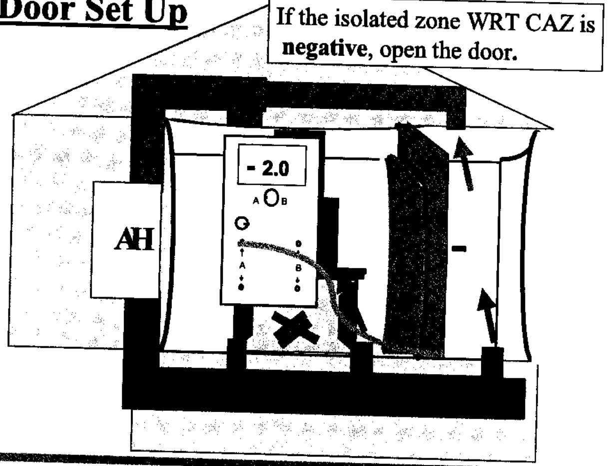
- With air handler operating (high speed if more than one speed);

CAZ Test-Air Handler Effect: Interior Door Set Up



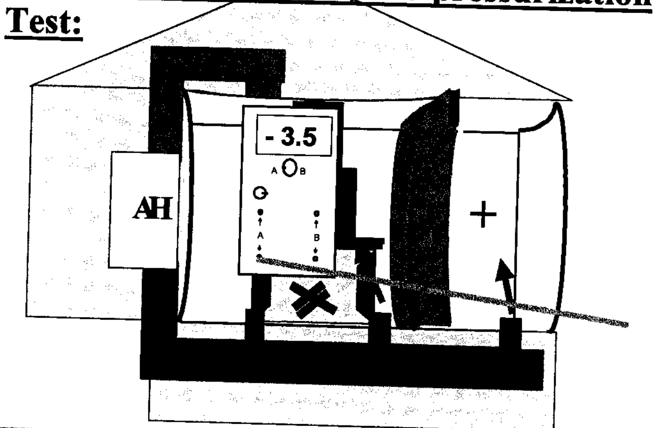
If the isolated zone WRT CAZ is **positive**, leave the door **closed.**

CAZ Test-Air Handler Effect: Interior Door Set Up



If the isolated zone WRT CAZ is **negative**, open the door.

Air Handler (AH) Induced Combustion Appliance Zone (CAZ) De-pressurization Test:



- Using the manometer, check the pressure in each zone isolated behind a closed door WRT to the CAZ.

1. If the zone behind the closed door is **positive** WRT to the CAZ, leave the door **closed** for the test

2. .If the zone behind the closed door is **negative** WRT to the CAZ, **open** the door for the test.

Test:

- Establish a baseline. With the air handler off measure the pressure in the CAZ WRT outside.

3. Turn on air handler to high speed.

4. Record pressure of CAZ WRT outside.

Example:

Baseline pressure = **-1.0 PA**
CAZ test = **-3.5 PA**

NET air handler effect **equals** CAZ test pressure **minus** baseline pressure.

NET air handler effect = -3.5 - (-1.0) = **-2.5 PA**

Interpreting Results:

If the net **Air Handler Effect** de-pressurizes the system by less than **3.0 PA** the system meets the PTCS Program Standard.

If the depressurization is more than 3.0 PA, modifications must be made to reduce the de-pressurization. If the supply ducts have been well sealed, the induced depressurization is most probably a result of door closer effects and may be mitigated by undercutting doors; installing transfer grilles or new returns into rooms without returns; or possibly providing supplemental make-up combustion air to the CAZ.

Warning!!: The test procedure described only measures air handler induced effects. The added effects of other exhaust appliances such as: bath fans, range hood exhausts, dryers, central vacuums, etc. may still induce back drafting. To ensure safety a worst-case test including these other appliances is recommended.

Pressure Pan Test

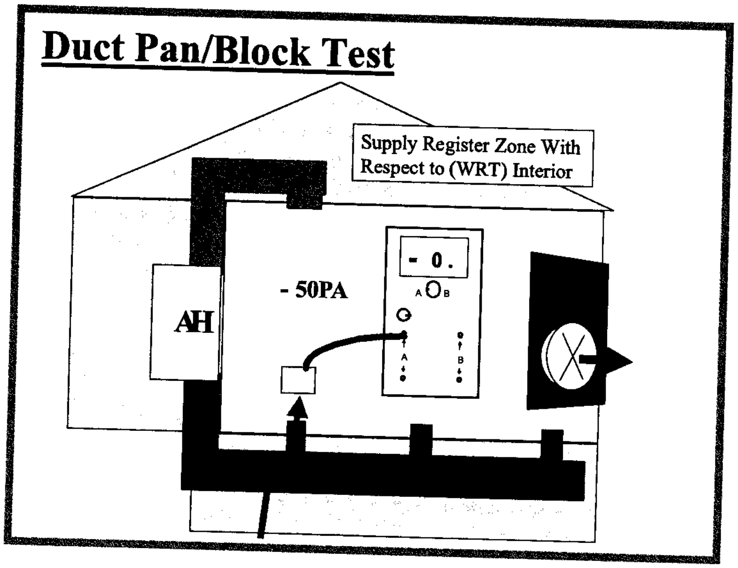
(This is a useful procedure **Not a required test)**

Testing Procedure

Application: Pan testing provides a quick, <u>qualitative</u> assessment of the leakiness of a duct system and helps to identify leak location.

Tools and Equipment:

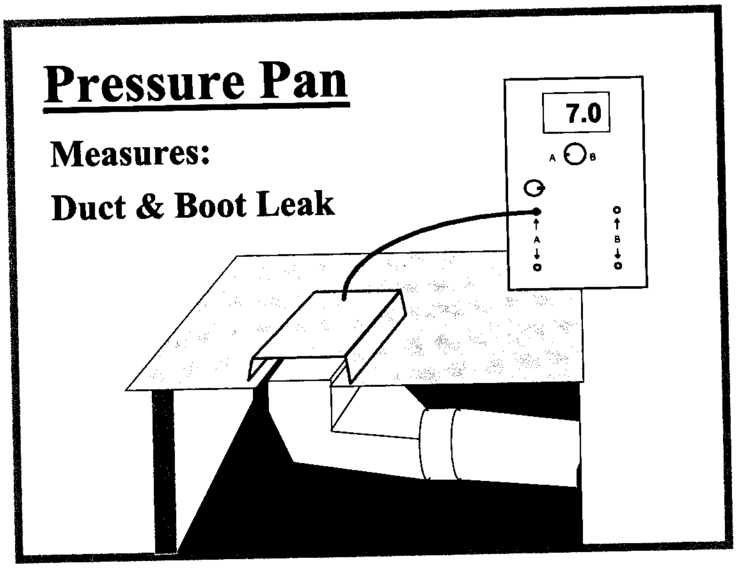
- Blower Door
- Digital Micro- Manometer (Accurate to **0.1** Pascal)
- Tape or Duct Mask
- Pressure Pan or Foam Block

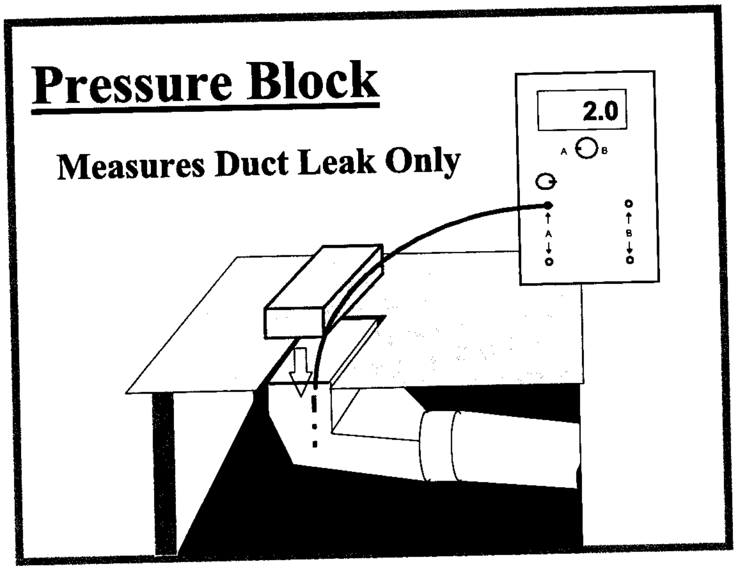


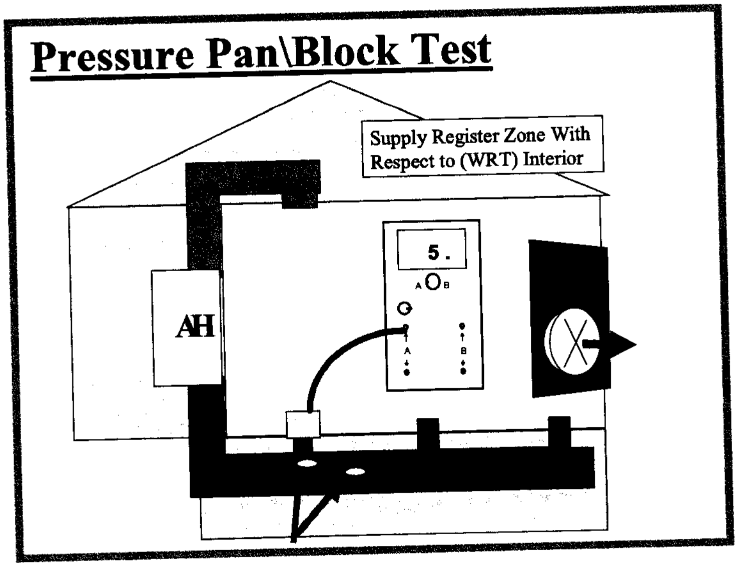
Duct Pan/Block Test

Setup:

- Setup and operate a blower door to maintain the house at **-50 Pascals** WRT outside according to the instructions for **Basic Blower Door Setup.**
- Set the air hanadler so that it cannot go on during the test.
- Make sure all exhaust fans and vented appliances are turned off.
- If using a Pressure Pan, seal all floor or ceiling to boot leaks before testing.
- Remove all system filters.
- Measure and record depressurization in buffer zones containing ducts (see procedure for **Zone Pressure** testing).







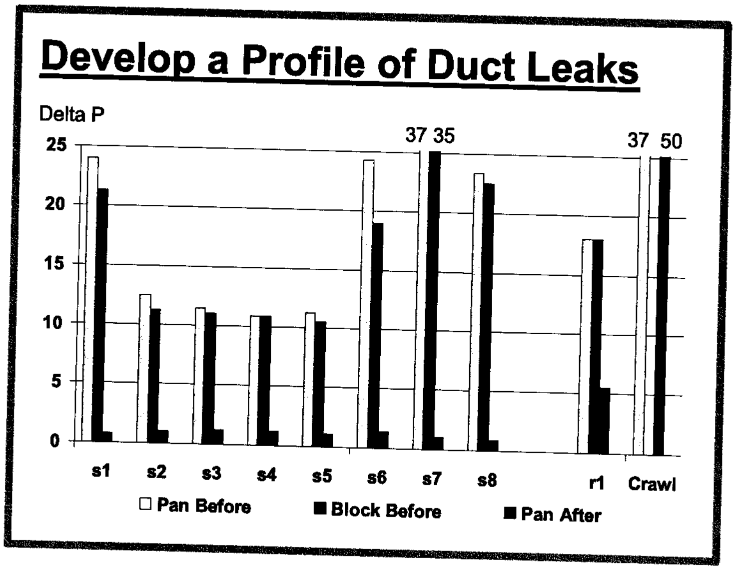
Test:

- With all the registers open, place the pan or block at each register to create a pressure boundary between the inside of the duct and the house.
- Using the manometer record the pressure in the duct WRT the house.

Repeat this procedure for each supply and return register in the house. Registers that are too large for the pan or which can't otherwise be covered such as toe kick registers should be taped with duct mask or masking tape and the pan pressure taken by inserting a pressure probe into the duct at the register being tested.

Note:
For each measurement, only the register tested is covered or blocked. All the other registers remain fully open to the house.

Interpreting Results:

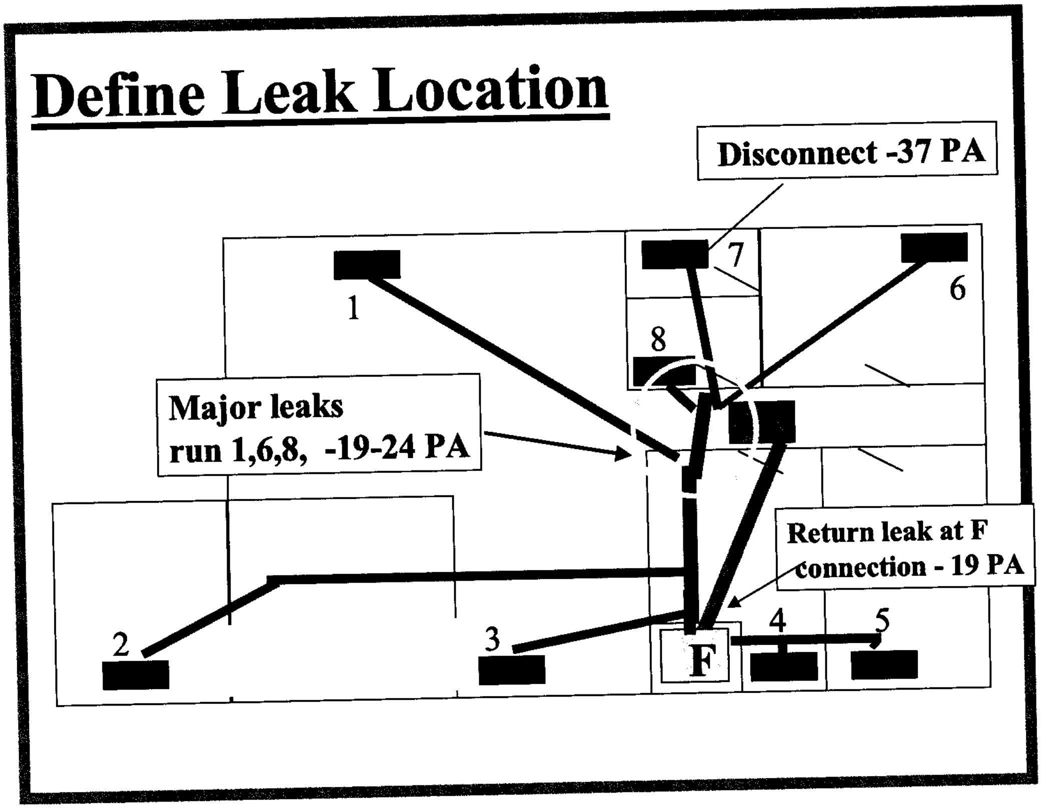


Generally higher pan numbers are associated with proximity to larger leaks in the system. If there is little leakage to the outdoors, all the pan numbers will approach zero. If there is a total disconnect at a register to a duct outside of conditioned space, the pan number at that register will equal the pressure in the zone containing the duct WRT to the house. When the duct zone is a well-ventilated attic or crawlspace the pan pressure for the disconnected duct will approach the pressure outside WRT to the house (in most cases 50 Pascals). All pan numbers in tightly sealed system would normally be less than 1 Pa.

The **pan number** represents the **ratio** of the size of the hole in the ducts connected to the outside compared to the size of the hole in the ducts connected to the interior of the house.

Example:
The pan numbers recorded above average about 17.5 on the supply side well above the program standard for a leaky system.
Supply register 7 with a pan number of 37 compared to the crawlspace (duct zone) pressure of 37 suggests a disconnect.
Registers S2 through S5 are all above 10 but consistent. In a system with a disconnect, these may represent a tight part of the system with little leakage that "sees" the disconnect from a distance.

Example:
Mapping the numbers from the previous page onto the schematic of the system helps to find potential leakage sites. Pan numbers are the only diagnostic test that point toward the location of the leak.



Define Leak Location

Disconnect -37 PA

Major leaks
run 1,6,8, -19-24 PA

Return leak at F
connection - 19 PA

Limitations: Pressure Pan testing is at best a qualitative assessment of duct tightness. Systems with many registers will tend to have lower pan numbers while small systems with only a few registers will tend to have higher pan numbers even if they have similar leakage areas. Adding registers to a system, enlarging a return or even removing a clogged filter can significantly lower the numbers even when no sealing is done.

Basic Blower Door Setup

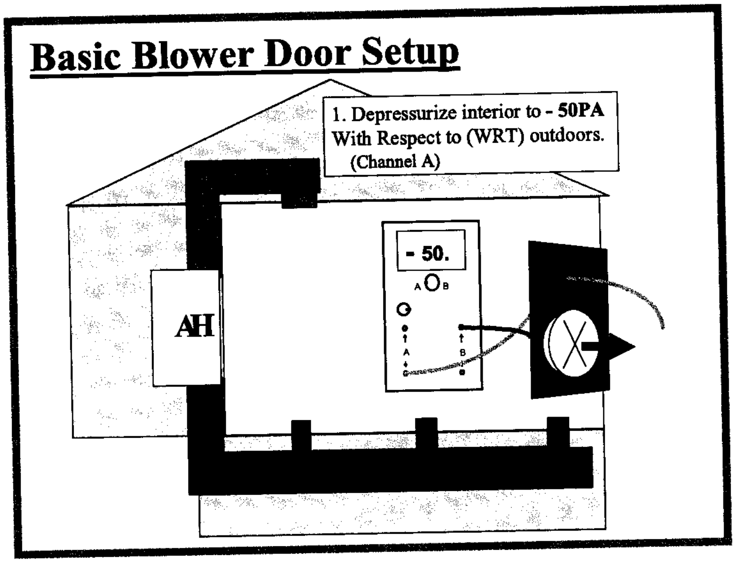
Application: The basic setup and operation of a Blower Door is an integral part of the ***Duct Leakage to the Exterior*** and ***Pressure Pan*** tests. The Blower door can also be used to verify the **Minimum Ventilation Level** (MVL) required for a house when there is no whole house mechanical ventilation system present.

Tools:

- Blower Door
- Manometer

Set Up:

- Open all register dampers.
- Close all exterior doors and windows.
- Open all interior doors
- Close fireplace or wood stove dampers and doors. Cover ash with wet newspaper (In some cases it may be necessary to tape opening).
- Turn down combustion water heater so it will not fire during the test (i.e. set to pilot and check to confirm pilot is still lit after testing. Re-light if necessary.).
- Turn off all exhaust devices including: clothes dryer, bath fans, kitchen fans, and central vacuum cleaner.
- Set thermostat to Off so HVAC system will not come on during testing.
- Turn all ventilation controls to Off position.
- Set up blower door. Channel A, pressure tap, house WRT out doors. Channel B, fan pressure WRT house.



Basic Blower Door Setup

1. Depressurize interior to - 50PA With Respect to (WRT) outdoors. (Channel A)

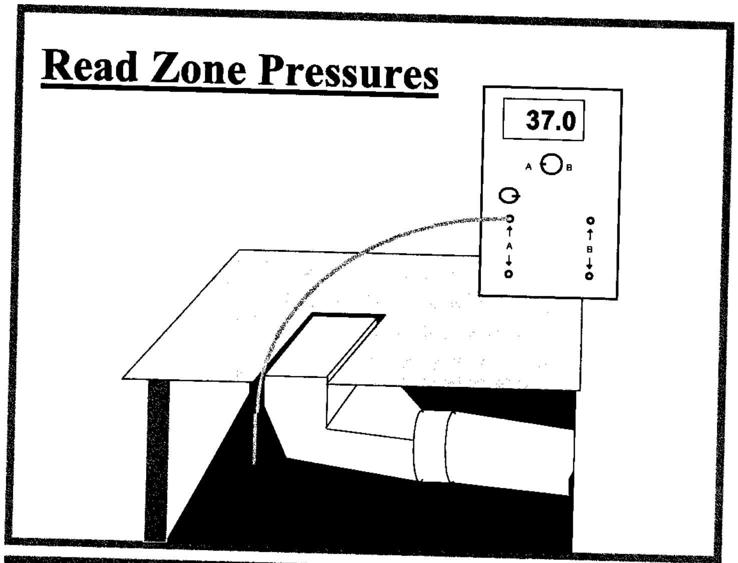
When testing is complete reset all thermostats and controls to original settings.

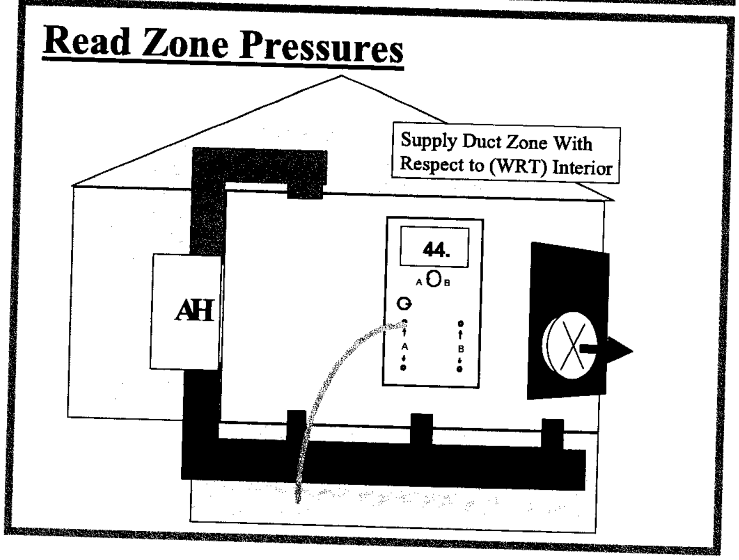
Test:
Adjust hole size and/or fan speed to pressurize or depressurize the house as needed.

Danger! Never perform test if any combustion appliance is operating; fires in fireplaces or wood stoves, gas ovens or range tops, etc.

Zone Pressure Testing

Application: Determination of pressure in one Zone with reference to (WRT) another. This test is especially useful for determining the pressure boundary of a building. When ducts appear to be outside of conditioned space in attics, crawlspaces, etc., or in other intermediate zones like floor cavities, this test determines to what extent these zones are connected to the outside. The information helps interpret Pan Numbers and other test results.

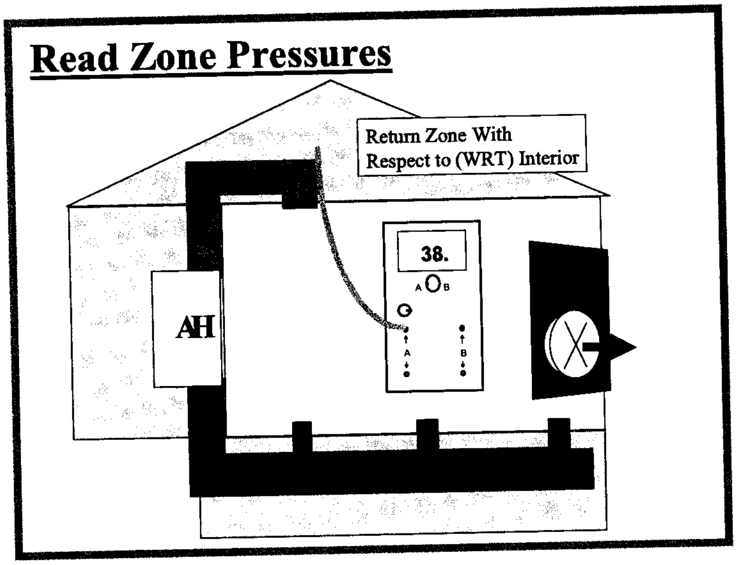

Read Zone Pressures


Read Zone Pressures

Tools:
- Blower Door
- Manometer
- Metal Probe
- Awl

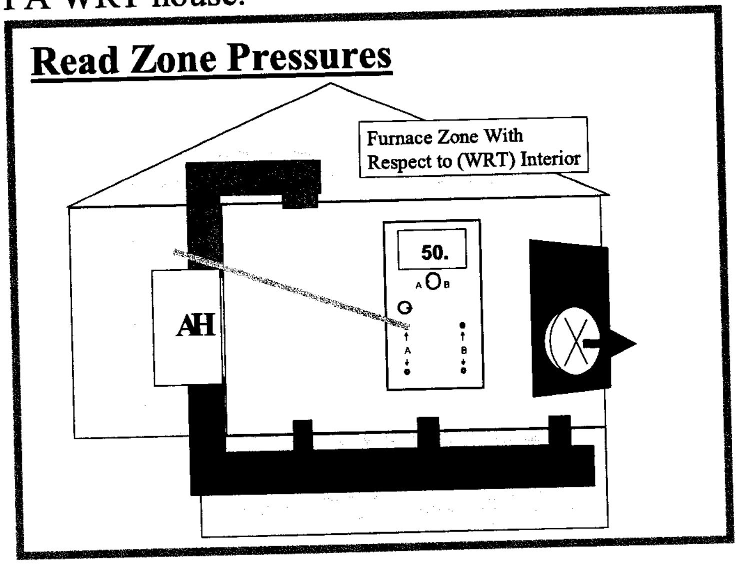
Set Up:
Set up house for basic blower door test. Determine access points between zones for pressure probe.

Test:
De-pressurize the house to - 50 PA using the blower door.
Insert pressure probe into zone to be tested.
Zones of interest: Attic, Crawlspace, Basement, Attached Garage, Wall Cavities, Floor Cavities between floors, Any Zone containing Ducts or the Air Handler.



Interpreting the results:

1. Any zone totally outside the house and totally connected to the outside should show the same pressure as the outside WRT the house i.e.. 50 PA or 0 PA if the pressure is measured as the zone WRT outside.
2. Any zone totally inside the house will be at the same pressure as the house and will show no pressure difference i.e.. 0 PA WRT to the house.
3. Zones with readings between 0 Pa and 50 PA WRT house are part of a series leakage path. Pressures closer to 50 PA WRT house will be in zones more closely connected to the outside. Pressures closer to 0 PA WRT house are more closely connected to the interior. A Zone at 25 PA is equally connected to the interior and exterior. An attic or crawlspace is considered well vented with a zonal pressure 47 to 50 PA WRT house.



Example

This Air handler (AH) is totally outside the conditioned area of the house.

Minimum Ventilation Level

Application: Whenever air sealing (including duct sealing) is performed, the overall tightness of the house envelope should be measured in order to estimate the potential for moisture and/or indoor air quality (IAQ) problems. The measured CFM50 of the house as determined from a blower door test may be used to estimate house ventilation as compared to suggested Minimum Ventilation Level (MVL) guidelines. Sealing a house below the MVL should only be undertaken if some provision is made or already exists to provide whole house mechanical ventilation adequate for the expected occupancy.

Standard: The ASHRAE standard for residential ventilation is based on providing **15 CFM** per occupant. In homes of typical size and occupancy, this is equivalent to approximately **0.35 air changes per hour (ACH).**

Calculations: The MVL for a house may be calculated based on: **(1)** the known number of occupants; **(2)** an estimate of the possible number of occupants based on the number of bedrooms; or **(3)** the air change rate and volume of the house. Generally the most restrictive of these methods should be applied to provide an additional margin of safety.

1. **MVL based on known occupancy:**

   MVL = (# of Occupants) x (15 cfm/occupant)

2. **MVL based on bedrooms:**

   MVL = (# of bedrooms + 1) x (15 cfm/bedroom)

3. **MVL based on ACH and volume**

$$\text{MVL} = \frac{0.35\ \text{ACH} \times \text{Volume of House (ft}^3\text{)}}{60\ \text{minutes}}$$

Each of these calculations yields an estimate of the required ventilation (in cfm) to maintain good indoor air quality.

The following formula **(4)** is used to convert the measured CFM50 from the blower door test to an estimate of the average ventilation potential (in cfm)

4. **Ventilation Potential = CFM50/N**

Where N is a correlation factor: N = C x H x S

C = climate factor, a function of annual temperature and wind. C = 20 is an appropriate approximation for most areas in the Northwest
H = height correction factor (see Table 2)
S = wind shielding correction (see Table 3)

As long as the measured **Ventilation Potential** is greater than the **MVL** additional air sealing should be possible without creating moisture and IAQ problems.

Table 2. Height Correction Factor

Number of Stories	**1**	**1.5**	**2**	**3**
Correction Factor "H"	**1.0**	**0.9**	**0.8**	**0.7**

Table 3. Wind Shielding Correction Factor

Wind Exposure	**Well Shielded**	**Normal**	**Exposed**
Correction Factor "S"	**1.2**	**1.0**	**0.9**

Example Calculation:

Given a 1200 ft^2 house with 8 ft ceilings, 3 bedrooms, single story, in an exposed windy site and 6 occupants with a tested CFM50 = 1800. Volume = 1200 x 8 = 9600 ft^3.

1. **MVL based on known occupancy:**

$$\textbf{MVL} = 6 \times 15 = 90 \text{ cfm}$$

2. **MVL based on bedrooms:**

$$\textbf{MVL} = (3 + 1) \times 15 = 60 \text{ cfm}$$

3. **MVL based on ACH and volume:**

$$\textbf{MVL} = (0.35 \times 9600) / 60 = 56 \text{ cfm}$$

The MVL based on occupancy of **90 cfm** is the most restrictive and should be used as the target value.

Using the values of **C** = **20** and **H** = **1** and **S** = **0.9** taken from **Tables 1** & 2.

$$N = 20 \times 1 \times 0.9 = 18$$

Calculating the **Ventilation Potential** = **1800/18 = 100 cfm** is greater than the MVL.

Limitations: The CFM50 of a house is a measure of the effective leakage area. Estimating the amount of ventilation that a given leakage area will provide is affected by many factors and is at best an approximation averaged over a wide range of conditions for the entire year. Periods of over and under ventilation will certainly occur. A properly sized and controlled mechanical ventilation system installed in a tight house envelop is the preferred alternative to assure adequate ventilation rates at all times.

Energy Star New Home Duct leakage Label

ENERGY STAR® Homes
Northwest Certified
Residential Air Duct

CHANGE FOR THE
BETTER WITH
ENERGY STAR

Company Information

Company Name ______________________________

Technician ____________________ Date ________

Duct Leakage

Cond. Floor Area (ft^2) ______________________

☐ yes ☐ no Air Handler in conditioned space?

☐ yes ☐ no Air Handler present during test?

If "yes" for either, then floor area x 0.06 = ______CFM@50 Pa

Target CFM is the above or 75 CFM@50 Pa, whichever is greater.

If "no" for both, then floor area x 0.04 = ______CFM@50 Pa

Target CFM is the above or 50 CFM@50 Pa, whichever is greater.

Circle Test Method: Leakage to Outside ***or*** Total Leakage

Test Result ____________________ CFM@50Pa

Fan Pressure ____________________ Pa

Ring (circle one) Open 1 2 3

Duct Blaster Location ______________________

Pressure Tap Location ______________________

Combustion Appliance Zone (CAZ) Test

	Main Zone	**Zone 2, if applies**
CAZ WRT Outside	______ Pa	______ Pa
Baseline, House WRT Outside (fans off)	______ Pa	______ Pa
NET CAZ Pressure (***subtract*** baseline from CAZ WRT outside)	______ Pa	______ Pa

Notes

Terminology

ACH – Air Changes per Hour.
CAZ – Combustion Appliance Zone.
CFM50 – airflow at an induced pressure of 50 Pascals. Hole Size.
MVL – Minimum Ventilation Level. Based on ASHRAE Standard of 15 CFM per occupant.
Pascal – metric unit of pressure. 1 inch of water column = 249 Pascals.
WRT – With Reference To. The pressure in the house was 25 Pascals WRT outside.

Table 1
Can't Reach Pressure (CRP) Correction Factors

Reference Pressure	CRP Factor 50 PA
10	2.85
15	2.19
20	1.81
25	1.57
30	1.39
35	1.26
40	1.16
45	1.07

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WASHINGTON STATE UNIVERSITY
EXTENSION ENERGY PROGRAM

Effective:
May 2011

2011 PTCS™ Duct Sealing Certificate & Sealing Form

Instructions: All sections must be filled out by a PTCS-certified technician at the time of installation. A copy of the completed form must be promptly submitted to the utility and homeowner in accordance with utility policy. Please enter online at www.ptcsnw.com or fax to Ecos IQ at 877-848-4074. Questions? Call 800-941-3867.

SECTION A: SITE INFORMATION

Technician Certification Number PTCS - _ _ _ _ _
Installation Company Name
Electric Utility Company
Customer Name
Street Address
Site Address 2 (Unit #/ Mailing Address)
City
State
Zip Code
Phone Number ( ) -

☐ Site Built (Existing)
Year Built: ________
☐ Site Built (New Construction)
☐ Y ☐ N Energy Star Home?
Foundation Type: ☐ Half Basement ☐ Full Basement ☐ Crawl ☐ Slab

Manufactured Home ☐ Y ☐ N
Sections ☐ 1 ☐ 2 ☐ 3
Energy Star Home? ☐ Y ☐ N
Super Good Cents? ☐ Y ☐ N

What type of heating system was installed at this site? ☐ Electric Forced Air ☐ Heat Pump ☐ Gas Furnace Other ________
Heated Area (sq ft)

Are at least 50% of the ducts in unconditioned space? ☐ Y ☐ N *If the majority of the ducts are in conditioned space, the home does not qualify for PTCS Duct Sealing.*
# of supply registers:
# of returns

SECTION B: DUCT SEAL DATA

House Pressurization Test - ***Required*** *for Existing Homes with Existing Ducts and Manufactured Homes*

Equipment Type ☐ Energy Conservatory ☐ RetroTec
Is this a Test-Only? ☐ Y ☐ N
Blower Door House Pressurized to: ☐ +50Pa CFM50 ☐ Other ________

Duct Leakage Test **(DB) = Duct Blaster** **(BD) = Blower Door**

				Leakage to Outside Test ONLY	
		New Construction	**Existing Home New Ducts**	**Existing Home Existing Ducts**	**Manufactured Home**
Pre-Test	**Pre Ring** (Circle One)	Not Applicable	Not Applicable	Open 1 2 3 H M L	Open 1 2 3 H M L
	Duct Blaster Fan Pressure	Not Applicable	Not Applicable	Pa	Pa
	Pre Duct Blaster CFM	Not Applicable	Not Applicable	DB CFM @ 0 Pa BD @ +50 Pa CFM	DB CFM @ 0 Pa BD @ +50 Pa CFM
Post-Test	**Post Ring** (Circle One)	Open 1 2 3 H M L	Open 1 2 3 H M L	Open 1 2 3 H M L	Open 1 2 3 H M L
	Duct Blaster Fan Pressure	Pa	Pa	Pa	Pa
	Post Duct Blaster CFM	**Flow @50Pa**	**Flow @50Pa**	DB CFM @ 0 Pa BD @ +50 Pa CFM	DB CFM @ 0 Pa BD @ +50 Pa CFM
	Compliance Path (Check One)	☐ **6% with AH** ☐ **4% no AH**	☐ **10%**	**Pre-Condition Leakage:** ☐ **>250 CFM or** ☐ **>15% of floor area** (Whichever is Less) **Reduction** ☐ **50% Reduction** ☐ **10% of Sq. Ft.**	**Pre-condition (check one)** ☐ **Single wide > 100 CFM** ☐ **Double wide > 150 CFM** ☐ **Triple wide > 225 CFM** **50% Reduction** Was furnace to plenum connection sealed? ☐ Yes ☐ No
	Duct Blaster Location	☐ **Return Grille** ☐ **Other** ________	☐ **Return Grille** ☐ **Other** ________	☐ **Return Grille** ☐ **Other** ________	☐ **Return Grille** ☐ **Other** ________
	Pressure Tap Location (Supply Register)				

Form continued on next page ►

Effective:
May 2011

2011 PTCS™ Duct Sealing Certificate & Sealing Form

SECTION C: COMBUSTION APPLIANCE ZONE (CAZ) TEST

A CAZ test is required if there are any non-sealed combustion appliances in the home.

Are there any combustion appliances in the house? ☐ **Yes** ☐ **No**

Combustion Appliance Type: ☐ Fireplace or Woodstove ☐ Gas Furnace ☐ Gas Water Heater ☐ Other: ____________

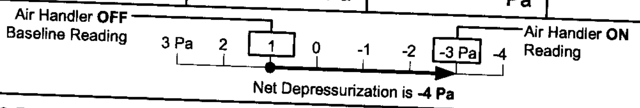
Baseline Pressure with reference to outside (all exhaust devices and air handler **OFF**) ____________ Pa

Weather conditions on day of test: ☐ Calm ☐ Windy

With air handler ON, record gauge readings below		**Internal Doors Open**		**Internal Doors Closed**	
	Zone Description	*Reading*	*Net*	*Reading*	*Net*
Zone 1		Pa	Pa	Pa	Pa
Zone 2		Pa	Pa	Pa	Pa
Zone 3		Pa	Pa	Pa	Pa

Net Depressurization Example

"Net" equals how much the pressure goes down when the air handler is turned ON (compared to baseline).



For systems to qualify, the air handler must cause no more than a -3 Pa net depressurization in any zone. Does this system qualify? (check one) **Yes** ☐ **No** ☐

Is there a UL-approved and functioning CO detector installed in the home? ☐ Yes ☐ No

A Carbon Monoxide (CO) detector installed in the home is required in all cases when a sealed or non-sealed combustion appliance is located in a conditioned space or attached structure, i.e. garage. RECOMMENDED CO detector specifications: UL 2034/CSA 6.19-01; digital display; peak CO memory and recall.

SECTION D: NOTES

Notes – *Attach additional sheets if necessary*

SECTION E: PTCS™ DUCT SEALING CERTIFICATE

PTCS™ Certification of Compliance – *To be completed by technician at the time of installation*

As a certified PTCS™ Duct Sealing Technician, **I certify** the Duct Sealing at this site and related equipment is in accordance with the standards set for the Performance Tested Comfort Systems (PTCS™) program.

PTCS™ Certified Technician Name (Print) ____________

PTCS™ Certified Technician Signature (Required) ____________

Completed Date ____________

PTCS™ Certified Technician Phone Number ____________

Customer Name ____________

Customer Signature ____________

Progress Energy

Failure to complete this application in its entirety and attach the invoice will result in a delay in processing your rebate. See back of form for details.

Home Energy Improvement Program Rebate Application - Duct

C Account Holder Name	Last Name	First Name	**Contractor Information**	
PEC Account Holder Address			Contractor Name	
City/State/Zip			Contractor Mailing Address	
Phone Number			City/State/Zip	
Email Address			Contractor Phone Number	
Payee Name (example: Landlord)	If different from account holder		Contractor Email Address	
Payee Mailing Address City/State/Zip	If different from account holder (include City/State/Zip)		Date of Service Completion	

Progress Energy Residential Electric 10-Digit Account Number

How did you hear about the program? ☐ **Progress Energy Website** ☐ **Contractor** ☐ **Utility Bill Insert** ☐ **Friend/Neighbor** ☐ **Energy Audit** ☐ **Email**

Sq. Ft. of home: ____ **Year your home was built:** ____

What type of home do you have? ☐ **Single-family** ☐ **Multi-family** ☐ **Manufactured**

How do you cool your home? ☐ **Central A/C** ☐ **Heat Pump** ☐ **Window Unit** ☐ **None**

How do you heat your home? ☐ **Oil** ☐ **Gas** ☐ **Electric** ☐ **Propane** ☐ **Other**

Duct Testing (limited to two units/dwellings) Duct testing must be completed on or before March 31, 2012 to be eligible for the incentive.

Airhandler Location	Duct Locations		Type of Testing	Readings	Test Cost	Available Incentive	Amount Requested
	☐ Attic	☐ Vented Crawl	☐ Pressure Plan	Please provide supporting documentation showing results	$	50% of cost up to $60	$
	☐ Attic	☐ Vented Crawl	☐ Duct Blaster		$	50% of cost up to $60	$

Duct Sealing/Repair Duct Sealing is strongly recommended to be combined with HVAC replacement.

Airhandler Location	Duct Location (check all that apply)		CFM Reduction # (if ducts were tested)	Repair Cost	Available Incentive	Amount Requested
	☐ Attic	☐ Vented Crawl		$	50% of cost up to $190	$
	☐ Attic	☐ Vented Crawl		$	50% of cost up to $190	$

Duct Sealing/Repair Checklist: Contractor must seal air leakage in all priority areas to qualify for the Duct Repair incentive.

The following standards apply to all accessible duct work:

Yes No N/A
☐ ☐ ☐ All ducts in nonconditioned areas (crawl spaces, attics, garages and basements) shall be fully wrapped or internally insulated

The following connections shall be sealed:

Yes No N/A
☐ ☐ ☐ Plenum seams (includes trunk lines, distribution boxes, etc.)
☐ ☐ ☐ Plenum to collars (tabbed metal collar sealed directly to rigid plenum material)
☐ ☐ ☐ Collars to ducts (mechanically fastened and sealed with bucket mastic or UL-181 approved tape)
☐ ☐ ☐ Ducts to supply boots (same as above)

Some or all of the following standards may apply, depending on the configuration & layout of the system:

Yes No N/A
☐ ☐ ☐ Cabinet seams / sealed with bucket mastic or foil tape
☐ ☐ ☐ Plumbing penetrations / sealed with caulk or adhesive patch
☐ ☐ ☐ Line set penetrations / sealed with high temperature caulk
☐ ☐ ☐ Panned returns / seal all vertical and horizontal seams
☐ ☐ ☐ Supply boots to subfloor / sealed from above or below
☐ ☐ ☐ Supply boots to ceiling/walls / sealed from above or below
☐ ☐ ☐ Return box to sheetrock and subfloor / sealed if building cavity is to used as part of duct system

Total Amount Requested $

For Duct Sealing/Repair, installations completed prior to January 31, 2012 are eligible for up to a $120 per system incentive. Installations completed on or after January 31, 2012 are eligible for up to a $190 per system incentive.

By signing below, I certify that as account holder, all data and information submitted in this Home Energy Improvement Program Rebate Application is accurate and truthful. In the event Progress Energy determines that the data and information submitted herein is inaccurate or misleading, I agree that Progress Energy may (in Progress Energy's sole discretion) withhold any rebate monies otherwise due. In the event Progress Energy has already tendered any rebate monies to the account holder and thereafter discovers the inaccurate or misleading information, account holder agrees to immediately refund Progress Energy all rebate monies received under this Home Energy Improvement Program Rebate Application.

Customer Signature ____ *Date* ____ *Contractor Signature* ____ *Date* ____

Please mail this completed application *and* a copy of your invoice to:

Progress Energy Carolinas – Home Energy Improvement Program c/o Honeywell Utility Solutions • 108 Rand Park Dr. Garner, NC 27529

Application must be received within 90 days of project completion to qualify for rebate • Allow 4 - 6 weeks for processing

PLEASE READ

INSTRUCTIONS FOR COMPLETING FORM

1. Verify that project meets program eligibility requirements. Obtain bids from program approved contractor(s) and select a contractor.
2. Have program eligible installation completed by a Prequalified Contractor. Contractor must be prequalified prior to beginning work.
3. Complete all appropriate sections of rebate application.
4. Return completed application within **<u>90 days</u>** of project completion along with itemized detailed invoice for work performed to the address below.
5. Keep copies of all documents submitted for your records.
6. A post installation visit and/or call may be required to verify that installation meets program guidelines.

TERMS AND CONDITIONS

1. Customer Eligibility

This Home Energy Improvement Program (Program) is offered to single, manufactured, and multi-family homes where there is a Progress Energy Carolinas (PEC) residential account. It is the responsibility of the Customer to assure that the application is filled out completely, signed by the Customer and the Prequalified Contractor, accompanied by documentation as required in the Documentation section below, **<u>and received within 90 days of project completion</u>**. All equipment must be purchased and installed prior to submitting the Final Application. Failure to provide any of the required information will delay or prevent processing of your application.

2. Prequalified Contractor Requirement

All work must be performed by Prequalified Contractors registered and in good standing with the Program. All Contractors must be prequalified prior to beginning of work for the PEC customer to be eligible for incentives. Work performed by other contractors or by the Customer is NOT eligible for incentives.

3. Energy-Efficiency Improvements

The Program will only pay incentives for the improvements specified on Home Energy Improvement Program Incentive Applications. All work must be in conformance with state and local code requirements. PEC has no obligations regarding and does not endorse or guarantee any claims, promises, work, or equipment made, performed, or furnished by any contractors or equipment vendors that sell or install any energy-efficiency measures.

4. Installation Verification

PEC reserves the right to require inspections and/or monitoring of the installation equipment listed on the Incentive Application form (hereinafter "Project") to verify compliance with the Home Energy Improvement Program as filed with the NC Utilities Commission in docket E2, sub 936 (hereinafter "Program") rules, verify the accuracy of project documentation, and verify equipment/system performance.

5. No Warranties

PEC does not guarantee the energy savings and does not make any warranties associated with the measures eligible for incentives under this Program.

6. Changes to the Home Energy Improvement Program

The Program may be modified or terminated without prior notice, and incentive offers may increase or decrease at any time.

7. Incentives

- Duct testing and duct sealing incentives are restricted to homes with ducted electric heat (electric furnace or heat pump). The incentive for Duct Testing is 50% of the cost, up to $60, for the first system tested. Testing of one additional system is incentivized at 50% of the cost up to $30 for the second unit. Duct testing must be completed on or before March 31, 2012 to be eligible for the incentive. The incentive for Duct Sealing is 50% of the cost up to $190 for each system treated. Installations completed <u>prior</u> to January 31, 2012 are eligible for up to a $120 per system incentive. Installations completed on or after January 31, 2012 are eligible for up to a $190 per system incentive.
- The incentive limits specified above limit what will be paid for the measure(s) to a Customer over the life of the Program and not merely for a single incentive application. One rebate check will be issued to the Customer applying for each approved and completed application. All incentives are paid to the Customer. **Please allow 4-6 weeks for processing**. Customer verifies that they have not received other incentives from any other programs for the installed measures requesting a rebate for this application in excess of the total installation costs. Potential tax liabilities are the sole responsibility of the Customer.
- The Program and associated incentive payments by PEC are for the purpose of PEC achieving its compliance and reporting requirements. The Applicant acknowledges that the incentive payment is an essential determination in Applicant's decision to participate in the Program. In consideration of the incentive payment and other benefits to Applicant, Applicant transfers (and PEC retains) any and all environmental, energy-efficiency, and demand-reduction benefits and attributes, including all reporting and compliance rights, associated with Applicant's participation in the Program.

8. Documentation

The cost of duct sealing must be itemized on the invoice. All invoices must include the Prequalified Contractor's company name, address, and phone number.

9. Rebate Application Mailing Address

Progress Energy Carolinas - Home Energy Improvement Program
c/o Honeywell Utility Solutions
108 Rand Park Drive
Garner, NC 27529
1.866.990.4347

For Internal Use Only:

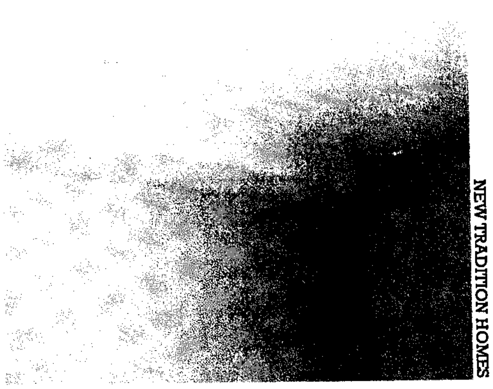
Rec'd:	1st Contact:	2nd Contact:	Missing:	15-Day Ltr. Sent:	Deact Ltr. Sent:

☐ Selected for Quality Assurance Inspections: (Date & Inspector)

☐ Work Completed According to Program Standards & Procedures ☐ Work Not Completed According to Program Standards & Procedures

Green Production Building—Moving Ducts Inside

Savvy builders can finance green features with the money homeowners would have spent on higher utility bills.



NEW TRADITION HOMES

The ducts in this Vancouver, Canada, home are between floors and hidden in chases.

by Ryan Kerr

The green production builder is responding to clients' wishes to build with the new goals of promoting better occupant health and environmental stewardship. The best part? Savvy builders can finance green features with the money homeowners would have spent on higher utility bills. The utility bill savings are generated by what is possibly the greenest building practice of all—energy efficiency.

The Building Industry Research Alliance (BIRA) is focused on supporting the design and construction of near zero energy homes as part of DOE's Building America program. As a member of BIRA, I have the privilege of working with some of the brightest building industry professionals to study advanced technologies and designs that promote Building America's ideal of net zero energy homes.

Even when energy-saving features do in fact save energy, additional work is needed to make them cost-effective in production home construction. The first step is to move from design to practice. The second step is market transformation. And market transformation is taking hold in Washington State, as two production builders implement a highly efficient, yet underutilized, design concept: moving ducts inside conditioned space (see "Chasing Interior Ducts," *HE* May/June '02, p. 24).

On a trip to visit BIRA research partners in the Pacific Northwest, I met with two production home builders who were moving all their homes' HVAC systems out of unconditioned attics, crawlspaces, and garages and into interior spaces. From the theoretical perspectives of technology and design, this technique is neither new nor advanced. From the construction perspective, however, it is hardly a mainstream practice, and it represents a very significant step toward increasing a home's heating and cooling energy efficiency.

In the world of production building, change means time, liability, and money. Thus builders are reluctant to adopt any new technique—but now that home buyers are beginning to recognize the value of energy efficiency, change can mean profit. The techniques used by our two builder partners are brilliant in their simplicity. And they are affordable, both in first costs, because they make use of construction efficiencies, and in operational costs, because they save energy.

Quadrant Homes

Quadrant Homes began building homes in the Seattle area in the 1960s. Today it builds more than 1,000 homes a year, mainly for entry level buyers. Quadrant is the largest builder in its geographic region and boasts industry-leading annual profit margins.

Quadrant Homes has obtained notable market results using an even-flow predictable scheduling scheme, in which it begins seven homes per day and finishes each house in precisely 54 days.

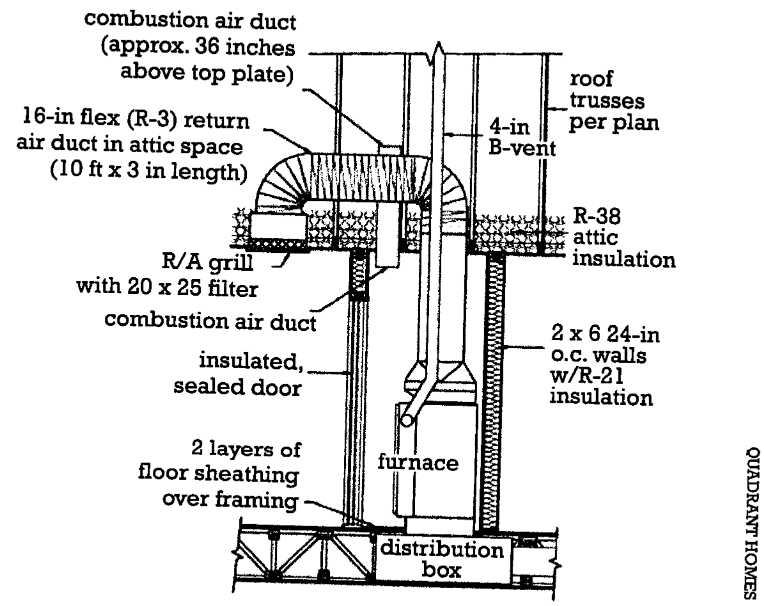
Using a standardized approach, Quadrant has achieved impressive results in both envelope and duct tightness testing, as performed by Washington State University (WSU) in both Energy Star and non-Energy Star homes. Quadrant's quality control is generally excellent. Although it can be challenging for a production builder to change methods, once those methods are changed, the improvements can be standardized and implemented across all homes, thereby improving thousands of homes.

One of Quadrant's subcontractors praises the even-flow production protocols, saying, "You know the job will be ready, you know exactly how much time you have, and you know you'll be alone to work in the absence of other subs." Another aspect in Quadrant's favor is its flexibility. Being open to innovation in the constantly changing world of green building gives the Quadrant homes an edge on the future.

What gave Quadrant the idea of moving its ducts inside? A research team from WSU was responsible for this suggestion. The team, consisting of Andrew Gordon, Chuck Murray, Mike Lubliner, and David Hales, approached Quadrant with the idea of moving ducts inside. In the broader context, Andrew Gordon was investigating how a prescriptive approach could be taken to reach 50% energy savings in heating and cooling and thus qualify Quadrant for a $2,000 federal tax credit for each home. As Andrew discovered,


NEW TRADITION HOMES

These New Tradition homes are two-story, with ductwork located between floors.


Quadrant Homes Typical Upper Floor Furnace Room Section

QUADRANT HOMES

Figure 1. Supply ducts are all located between the first and second floors, running parallel and perpendicular to the open-web, or parallel flat chord trusses.

building energy simulation software tools continually pointed to decreasing envelope leakage and moving ducts inside as the best options for cost-effective energy savings that were above Energy Star requirements.

Quadrant already had the tight envelope, and it happened to be in the midst of redrafting its home designs. As Quadrant was testing the waters with tax credit homes—Energy Star homes with added attic insulation and an improved AFUE (annual fuel utilization efficiency) furnace—it was the right time to make wholesale changes to the company's HVAC designs. The next time Andrew met with Quadrant's design team, they had worked with their HVAC subcontractor, Bob's Heating, to design a new system (see Figure 1).

The most important element of the new design is that the supply ducts are all located between the first and second floors, running parallel and perpendicular to the open-web, or parallel flat chord trusses. The open-web trusses allow Quadrant subs the flexibility to run plumbing, electrical, and ductwork through the open webbing between the second-floor trusses.

Quadrant switched to open-web trusses five years ago in order to panelize the second floor in its homes, thereby saving a day per home in its tight construction schedule. The additional costs for the new truss design were offset by cost savings in the HVAC system equipment and installation. These cost savings were made possible by shorter uninsulated duct runs and the purchase of smaller, less expensive furnaces. These in turn were made possible by the reduced heating load caused by moving the HVAC system inside.

Although Quadrant no longer panelizes its floors, it has stuck with the open-web trusses because the subs wouldn't have it any other way. The 18-inch open-web trusses also streamline construction when buyers choose optional floor plans that require longer second-floor truss spans. The longer truss spans do not require additional bearing walls, as they did when the design called for I-joint trusses.

Quadrant also moved its furnace from the attic to a mechanical closet on the second floor. According to WSU's David Hales, it is better for the homeowner to have the air handler located in a mechanical room, where service or replacement is easier. The mechanical closet is actually built to outside-space code requirements (with insulated walls and door) to accommodate an 80-AFUE furnace with nondirect venting. A 90+ AFUE furnace, as required by Energy Star, would not require this feature, although it would require other features, such as a gas condensate drain. Quadrant is not prepared to make a wholesale upgrade to 90-AFUE furnaces, mainly because an improved furnace is one of many optional energy-efficient upgrades that it offers to its buyers.

Quadrant's return ductwork is still in the attic. The duct is insulated to R-8, per Washington Building Code, and surrounded by additional insulation in some areas. This configuration is difficult to model using many building energy simulation tools, but with all the supply ducts and the furnace within conditioned space and minimal return duct in the attic, this HVAC system is greatly improved.

The HVAC contractor. One of the most important elements in making a smooth transition to a new building practice is close coordination among the affected trades. Wade Craig, of Bob's Heating, began working with Quadrant eight years ago to introduce 90-AFUE furnaces as optional equipment. As customers began to choose this option, Quadrant looked to Energy Star for guidance and today, as we have seen, it is moving its ducts inside.

When I asked Wade about moving ducts inside, his first response was "Anything we can do to get our guys out of the crawlspace is great." According to Wade, ten years ago almost all homes in Washington had ducts in the crawlspace. This is a problem for several reasons, not the least of which is the working conditions, and subsequent quality issues, for the HVAC trades. It is easier for installers to do a quality job in the home when they are not lying in mud, deep in a corner of the crawlspace, where they know an inspector will not crawl around to inspect their sealing around boots and the like.

In addition, when ducts are installed between floors they are clearly visible to the general contractor and inspector. Another major concern is trade damage or trade fighting, which occurs when electrical or plumbing subs compromise ducts to squeeze their work into place. With open-web trusses there is enough room for all trades, making each sub's work easier, and of higher quality.

Wade says his firm can make more economical bids for HVAC work when ducts are inside, as they save on material (the runs are shorter), save on insulation (there's no need for insulation inside), and save on labor (it's easier).

I asked Wade what he would tell builders who were considering moving to open-web trusses and moving the HVAC system inside. Here are his two biggest pieces of advice:

1. Don't be afraid of the additional costs for open-web trusses. This includes the cost of adding at least 4 inches to the height of the home, to make room for ducts. The additional costs will pay for themselves for many reasons. Callbacks will decrease; subs can coordinate their work more easily; many trades can bid less for jobs because it is easier to run equipment between floors; and builders can save on materials, because open-web trusses allow for longer floor truss spans, as explained above.

2. Work with your HVAC sub to design a system that works for both of you. This is imperative for any design change that influences the way subs complete their work.

Caveats. Many builders assume that with ducts inside, duct leakage is less important. However, problems can occur when the ducts are located between floors and the rim joists are not properly insulated and sealed. Ducts must be well-sealed with mastic, and tested with a Duct Blaster for quality assurance. Duct leakage could result in significant losses to the outside through thermal and air leaks. If the ducts leak, rooms farthest from the air handler may not receive adequate air flow. There are excellent sealing and insulating protocols in the manuals referenced at the end of this article.

NEW TRADITION HOMES

The duct in this New Tradition home under construction is a trunk between floors that supplies the first floor through ceiling registers and the second floor through floor registers.

Factors in Quadrant's easy transition. Ready for innovation and open to change, Quadrant is flexible, and its flexibility has allowed it to evolve. These factors also had a hand in Quadrant's easy transition:

- Quadrant's HVAC sub is a champion for moving ducts inside and was involved in original design review.
- Quadrant builds entry-level homes with few architectural elements that could complicate sealing and HVAC design.
- Quadrant was involved in a redraft of designs when WSU suggested moving the ducts inside.
- Quadrant was already using open-web floor trusses, which made the transition easier.
- Quadrant's systematic approach to building made it easier to effect a wholesale change.

New Tradition Homes

New Tradition Homes, headquartered in Vancouver, Washington, serves new home buyers in the western and central parts of the state. New Tradition Homes has been a Building America partner for several years and is one of the few builders we work with that have an

Thermal Barrier and Duct Locations

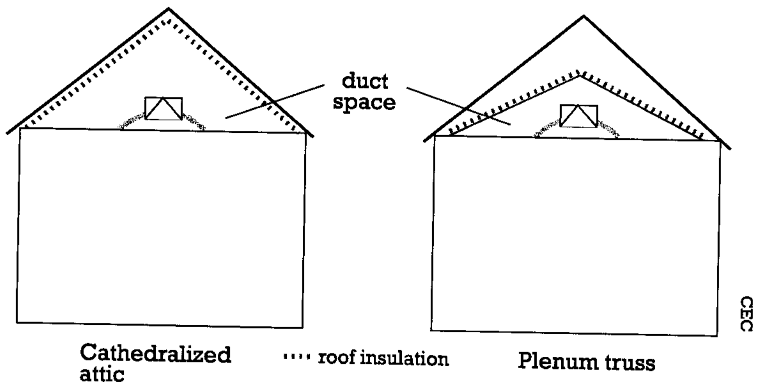


Figure 2. Here is a schematic of the thermal barrier and duct locations for keeping ducts inside conditioned spaces while using a cathedralized attic or a plenum truss.

integral building science team whose members represent a cross section of the company's operations. This structure enables the builder to make smooth transitions to cost-effective design changes. New Tradition Homes works with Building Knowledge, a residential building science firm, as well as WSU and BIRA, to identify, test, and implement new designs and technologies. New Tradition built over 400 homes in 2005, but it has decreased its construction pace in recent years with the tightening of the local home market.

Like Quadrant, New Tradition has begun to move ducts from the crawlspace and attic to the inside of its homes. It began by planning the move with its HVAC subcontractor. With planning, the process was relatively painless for New Tradition, with cost increases estimated at about $500 per home. However, with future redesigns, New Tradition Homes hopes to eliminate cost increases or actually to save money by moving the ducts inside. The loss of floor area was not an issue for New Tradition, as the homes are two-story models, with the ductwork located between floors. The air handler was included in the envelope by extending the conditioned space into the garage. Indeed, the only difficulty was that New Tradition wanted to integrate the improvements into homes already under construction and was unable to do so. This illustrates the need to address HVAC improvements in the design, rather than in the building, phase.

New Tradition Homes runs a supply duct perpendicular to and beneath the first-floor trusses. New Tradition uses a typical closed-web truss that makes running large ducts perpendicular to trusses within the floor cavity nearly impossible (see photo, p. 26). Given that the duct is underneath the first-floor trusses, an air barrier is not required as it would be if the duct were underneath the second-floor ceiling. However, the first-floor trunk required additional coordination between the HVAC sub and the framing sub, because the ducts went in after framing was complete and the framer then returned to frame the ceiling chase around the duct. This process is easier for a production builder than it is for a custom builder, because in production building, the trades are typically working on other homes in the same community and can easily coordinate to come back and finish the job.

Caveats. The same caveats apply to New Tradition as to Quadrant. Proper sealing of ducts and rim joists is essential. Here again, ducts should be tested for leakage (before the drywall goes in, while remedial actions can be taken), and the envelope should be tested for airtightness.

Factors in New Tradition's easy transition. Again, a willingness to try something new was just as important as having the tools and skills with which to do the work. These factors also contributed to New Tradition's easy transition:

- New Tradition Home's building science team facilitated its smooth transition by being open to any new improvements in energy efficiency building design.
- Because New Tradition is constantly learning, it had the background and the technical support to move ducts inside cost-effectively.
- New Tradition works with a willing and able HVAC subcontractor.
- Homes are two-story with 9-foot ceilings. (A 1-foot furred-down chase is not a significant intrusion on inside space.)
- New Tradition is already building quality homes using Building America best practices. This includes well sealed ducts and rim joists that ensure that ducts are actually within conditioned space.

Moving forward, New Tradition is examining all of its plans and redrafts to move ducts to inside spaces. As part of its systems approach, New Tradition is determining how fur-downs, dropped hallways, and other features that are needed to move ducts inside can be used to improve architectural elements within the home. For example, entering a bedroom with a 9-foot ceiling from a dropped hallway with an 8-foot ceiling gives the occupant a sense that the bedroom is larger than it is. The difference in ceiling height also serves to break up and define the spaces.

New Tradition will consider open-web trusses on future homes because open-web construction makes it easier to run ducts between floors and makes it easier for other trades to do their work, as explained above. This would require some changes in construction procedures, however.

Builders Roundup

Both Quandrant Homes and New Tradition Homes focused on getting most of the supply ducts in between floors. Their most important reasons for doing this were that the homes have two stories, and that the approach is cheap, doesn't require major redesigns, and is not a far leap from current practice. Quadrant, using a standardized approach, will place all of its air handlers in second story outside-space mechanical closets, regardless of plan type or furnace type. These techniques include moving conditioned space around the furnace in the garage and building an insulated closet around the furnace in the garage. It is important to note that if one uses this latter technique, it is critical to insulate the slab under the furnace. New Tradition dropped ceilings only where necessary, and only in hallways, closets, bathrooms, and small soffits in other living spaces. Quadrant, with its return in the attic and its open-web trusses, will be able to contain all ducts within the mechanical room and the attic, and between floors.

What About Other Techniques?

There are many options for moving ducts and HVAC equipment inside. Our research team was partial to the techniques discussed in this article. However, each home builder will have its own issues and practices, which may make the following options better suited to its particular situation (see Figure 2).

Cathedralized attic. A cathedralized attic is insulated at the roof deck, rather than above the top floor ceiling, or lid. When the cathedralized attic contains the ducts, it is not conditioned, nor is it vented to the outside, which creates a semiconditioned space. This technique is often used if the builder is trying to create a bonus room in the attic. However, it is difficult to insulate the roof truss to as high an R-value as the lid, because of the amount of space required to adequately insulate. Often builders will use spray foam insulation in this case, but this is significantly more expensive than batt insulation. Other drawbacks include increased conditioned space and, most significantly, increased wall area coupled to the outside.

Plenum truss. The plenum truss approach utilizes adapted roof trusses that are designed to create semiconditioned space in the attic for ductwork. The plenum truss is a center section of the truss raised to provide a section for HVAC equipment and ducts. This design creates a plenum area in which supply ducts from the unconditioned attic are run. The interior of the plenum space is finished with an air barrier, isolating the ducts from the unconditioned space. Then the ceiling drywall and insulation are installed as appropriate. This method can be costly. (The photo above shows the air handler in the extended conditioned space of the garage.)

Building Forward

New Tradition Homes and Quadrant Homes are changing one of the important details in the design of their homes by moving the HVAC equipment inside. As the home market continues to tighten and Americans focus on energy efficiency, health, and greening their lifestyle, builders who are improving their homes today will be in a position to enjoy greater market success tomorrow. BIRA believes the techniques displayed by these two builders hold great promise for builders across the country. The methods discussed are cost-effective while offering benefits beyond energy savings, especially concerning the move to open-web trusses. Both builders have found systems that work for them—systems that exemplify how production builders can improve their homes in a cost-effective manner. We are proud to work with these builders, and we hope that America's production home builders take a page from their book to change the way their own homes operate, for the benefit of themselves and their customers. It can be done.

The air handler is located inside the New Tradition home by extending the conditioned space into the garage.

Ryan Kerr is a market and design analyst for ConSol in Stockton, California. ConSol is an energy consultant to productions builders.

For more information:

Andrews, J. *Better Duct Systems for Home Heating and Cooling.* Building America, 2007. Can be downloaded from: www.eere.energy.gov.

Headrick, Roger. *Home Builders Guide to Ducts in Conditioned Space.* Park Ridge, IL. California Energy Commission, 2003. Can be downloaded from: www.energy.ca.gov/reports.

DOE's Building America program is a public/private partnership composed of six teams that provide energy solutions for production home builders. One of these teams is the Building Industry Research Alliance (BIRA). Led by ConSol Energy, BIRA is a group of building industry professionals dedicated to advancing home performance in communities whose goal is to produce as much energy as they consume. For more on Building America and BIRA, go to www.bira.ws.

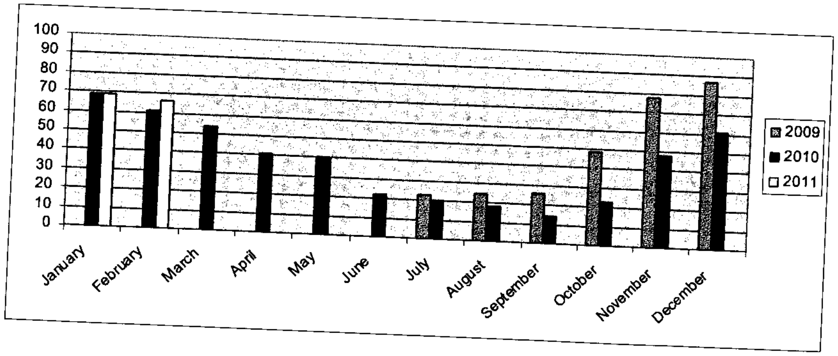
SAGE BUILDING SOLUTIONS

Energy Efficiency Through Building Science

Sage Building Solutions, a local green building contractor will discuss various energy efficiency testing methods to determine home energy performance.

Various rebates and financing options are available for homes that are properly tested and certified.

A local energy efficiency pilot program will be discussed with a Q&A session will follow.

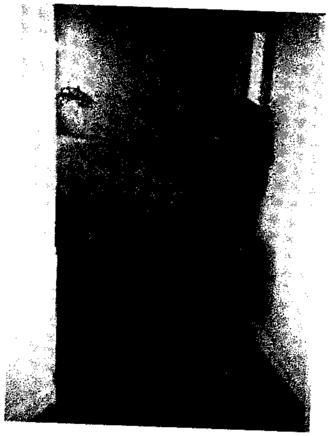


Blower Door Test

Duct Blaster Test

Infrared Thermography

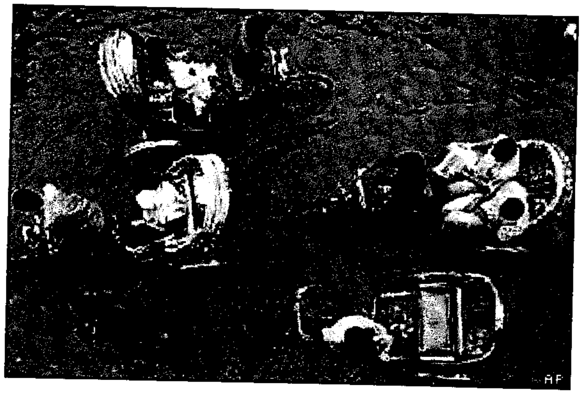
Fan Watt Draw Test



The Big Picture

NASA

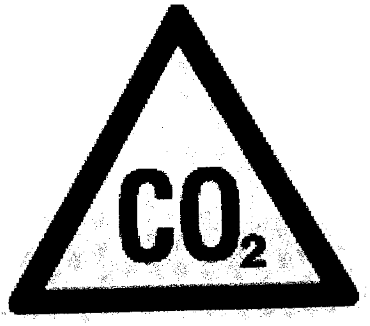
Effects of Global Warming in Our Lifetime



- *More extreme weather events
- *Disruption of food production and the food chain
- *Disruptions of ecosystem services, including water supplies
- *Spread of disease, e.g. West Nile, Malaria
- *Submersion of land masses 20-40 feet

Source: Intergovernmental Panel on Climate Change, EPA

CO_2 Status

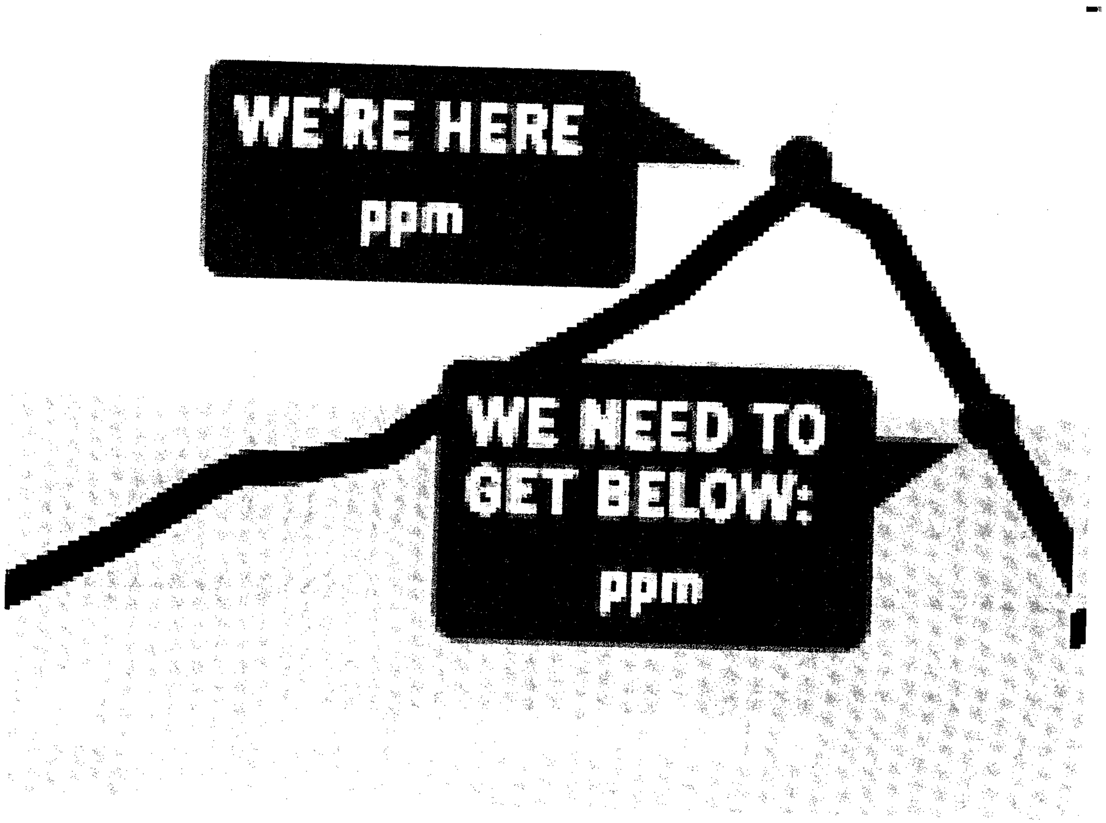


- 350 ppm of CO_2 considered the threshold beyond which the dangers of global warming increase.

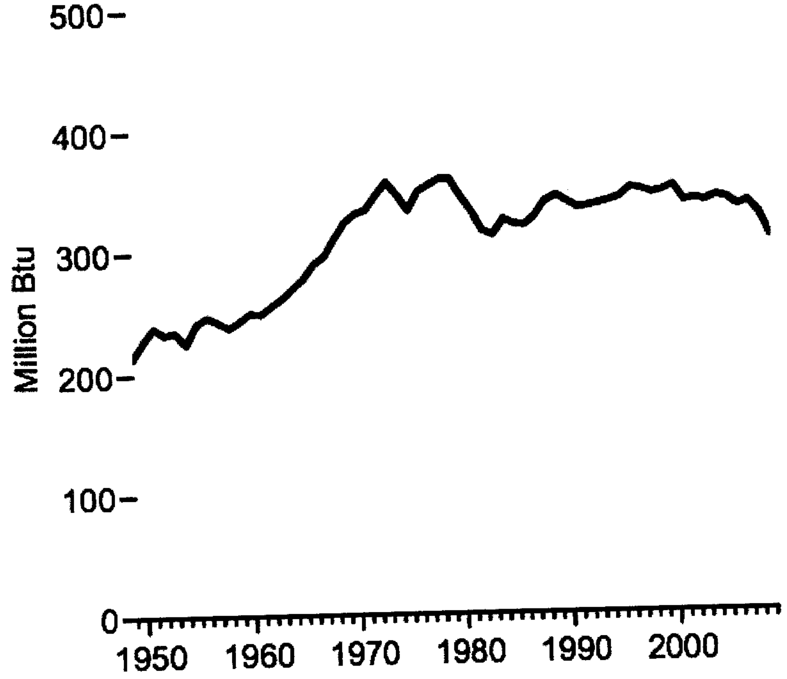
- Current level = 389 ppm (at least 650,000 yr high) and expected to pass 400 ppm within a few more years.

www.350.org

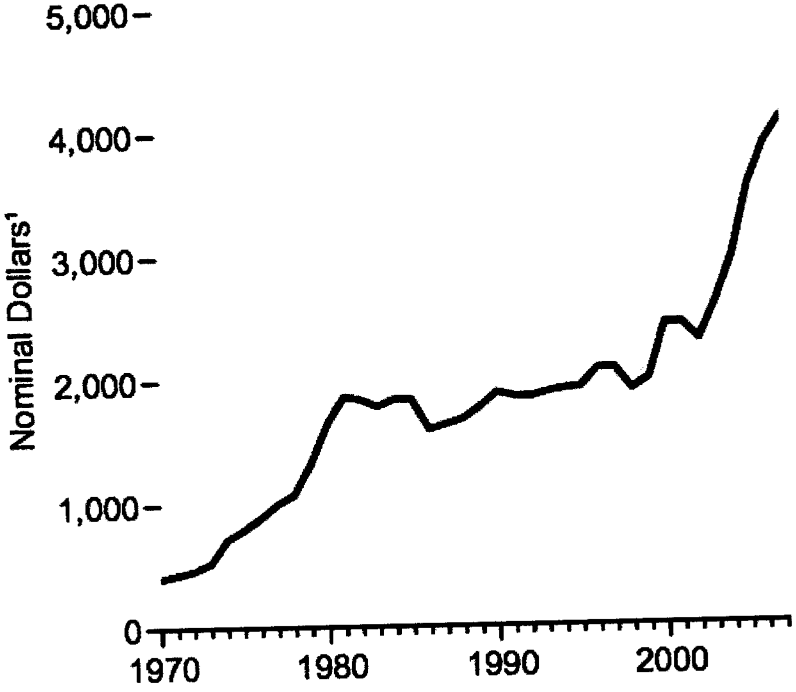
www.350.org



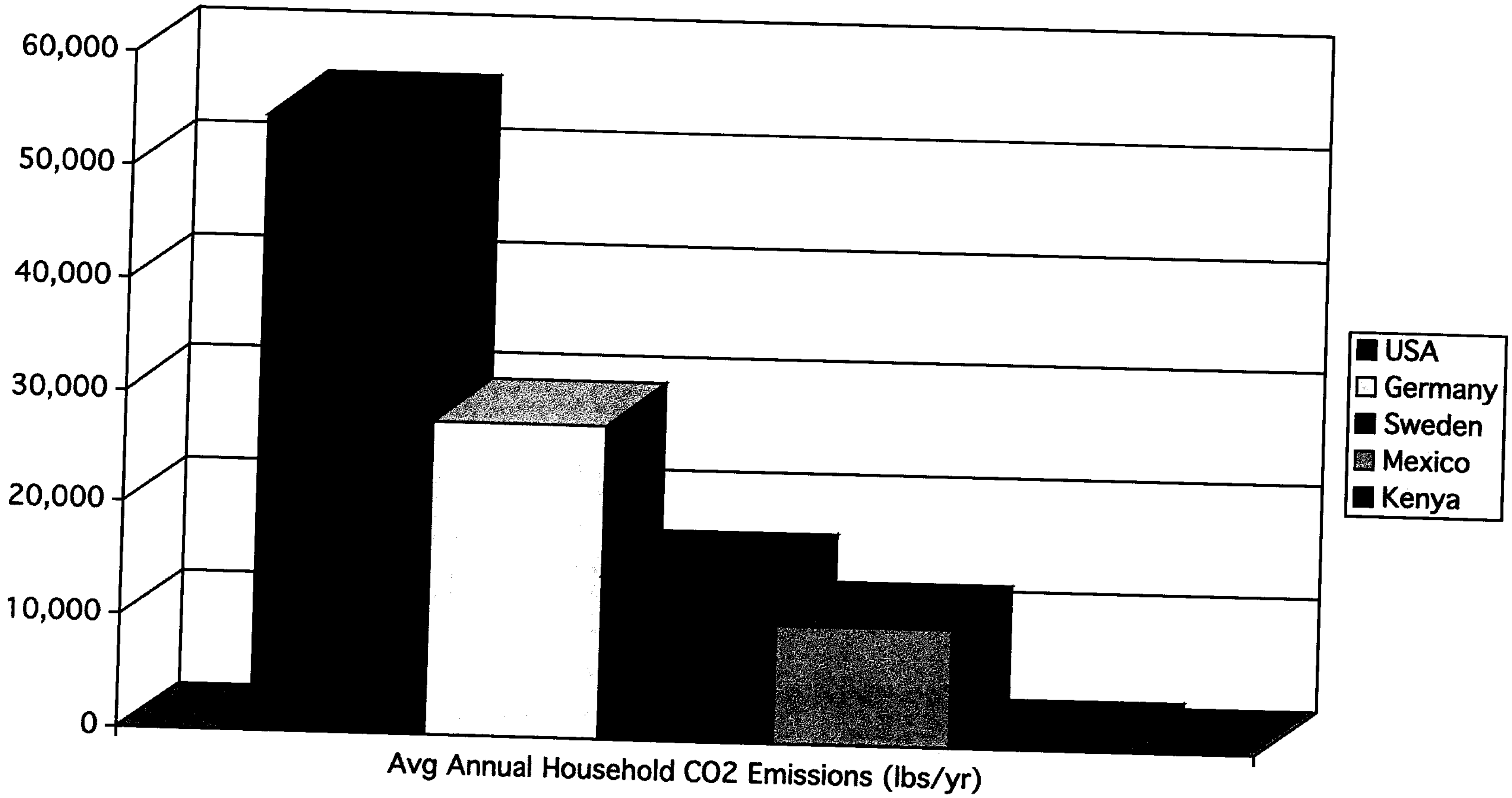
Energy Consumption per Person, 1949-2009



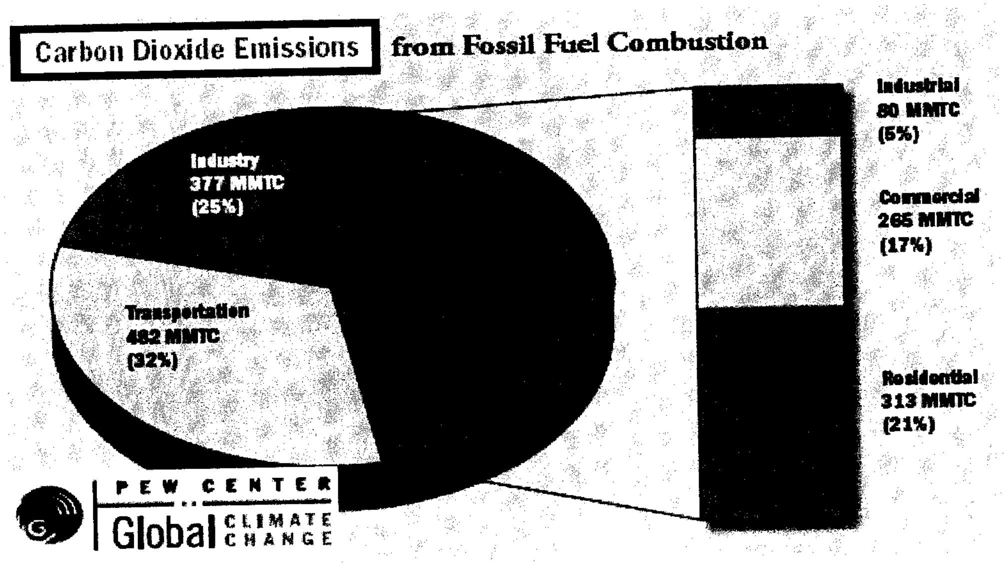
Energy Expenditures per Person, 1970-2007



How do US household CO2 emissions compare globally?



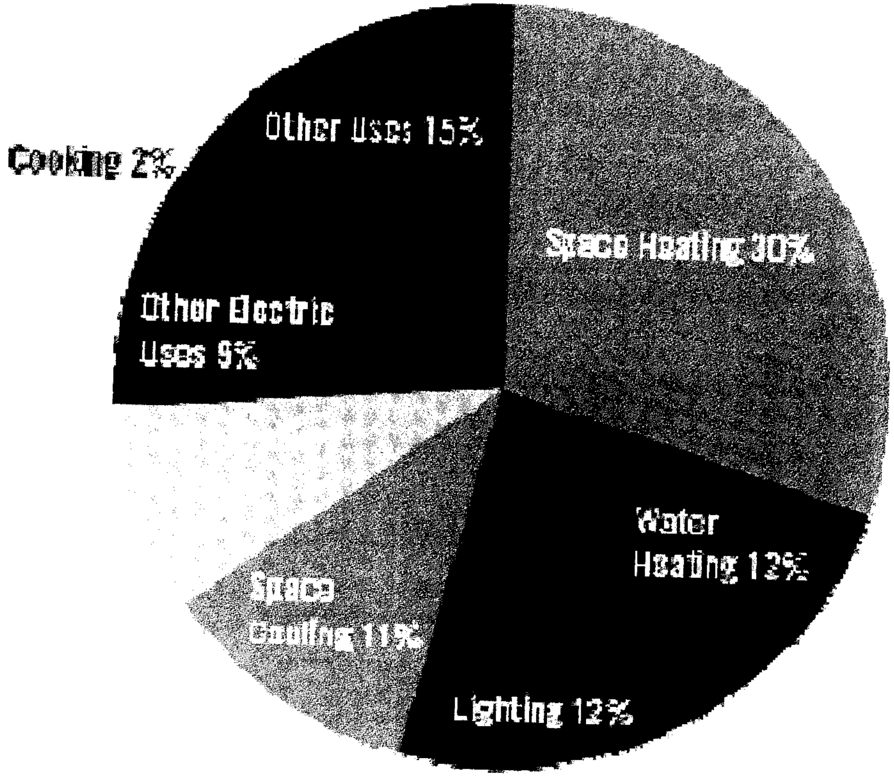
US Carbon Footprint



10%
CARS

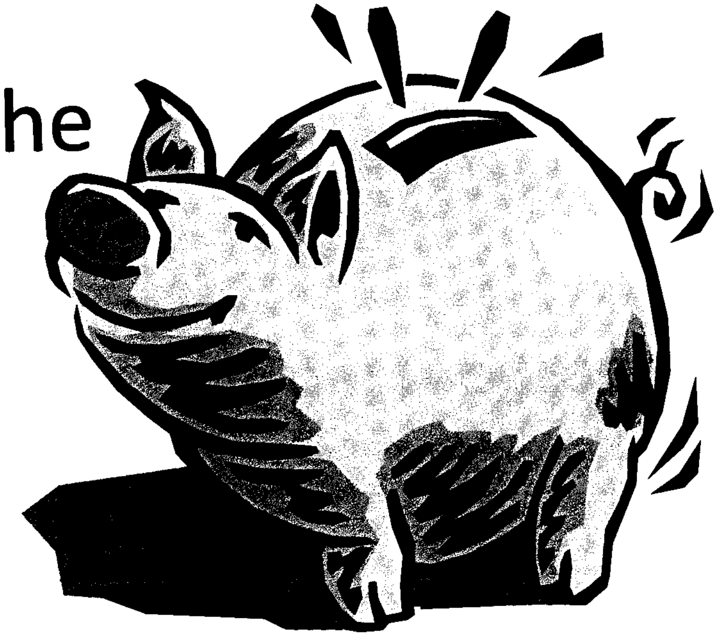
20%
HOMES

Where Does It All Go?

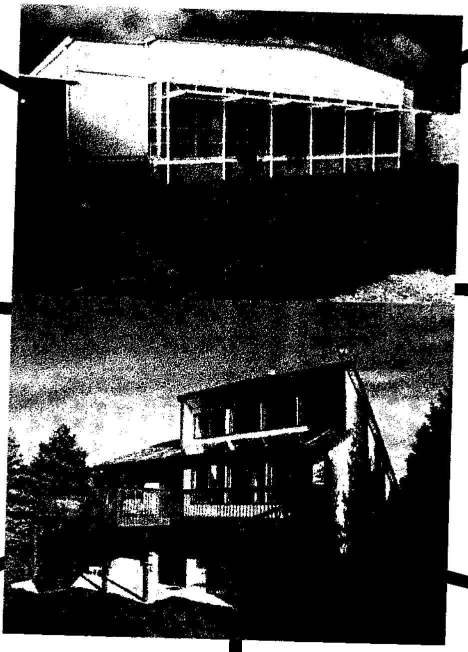


Why focus on Energy Efficiency?

- Saving energy is cheaper than generating it:
- The cheapest watt is the "NEGAWATT"
- Tax rebates & grants available NOW



Big Picture: past & current



Courtesy of DOE/NREL

PV rebates

Cool roof rebates

Solar Hot Water rebates

Weatherization rebates

Lighting rebates

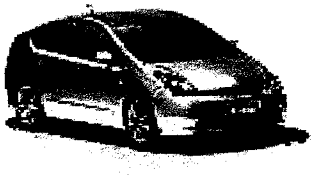
Energy Star

Etc.

Car performance

1 **Products**

2 **Performance**



?

Miles
Per
Gallon
60

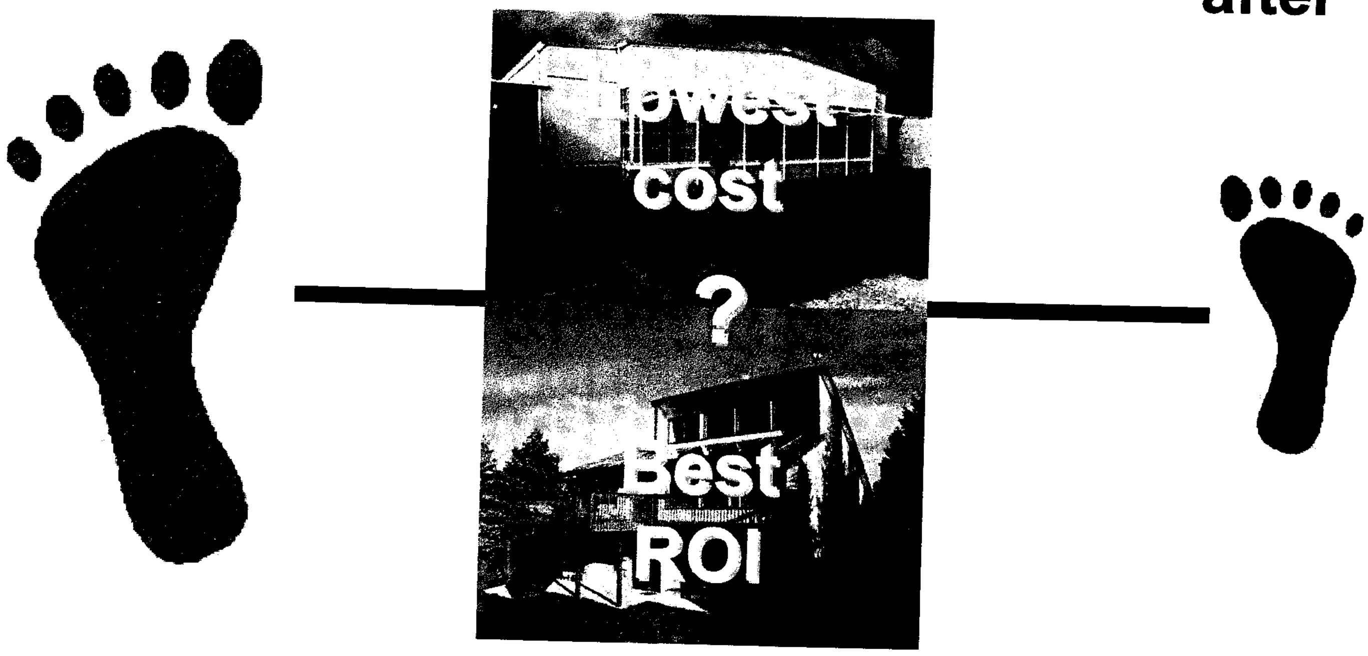
Big Picture: future trend

Energy footprint

before

Energy footprint

after

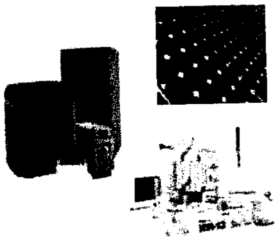


Courtesy of DOE/NREL

REDUCE IT! You figure out how, and the more you do, the more rebate money you'll get.

Home Performance

① **Products**



② **Performance**

?

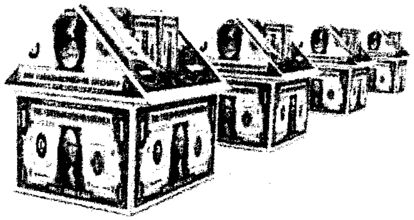
Home
Energy
Rating
System
85

What is Home Performance

- Systems not Products
- Building Science
- Its about Performance (results)

Comprehensive Home Performance

1. Whole house assessment
2. Multi-trades with specific quality standards
3. Post work commissioning
4. Q/A and Verification

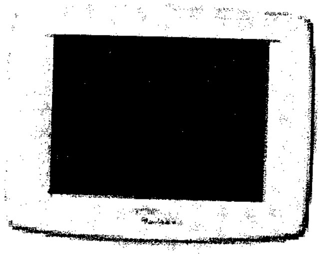


FINANCIAL

Save 30-100% on energy bills while improving comfort

HEALTH

Eliminate allergens, pollutants and sources of respiratory disease



COMFORT

Eliminate drafts and keep constant temperature year-round

ENVIRONMENT

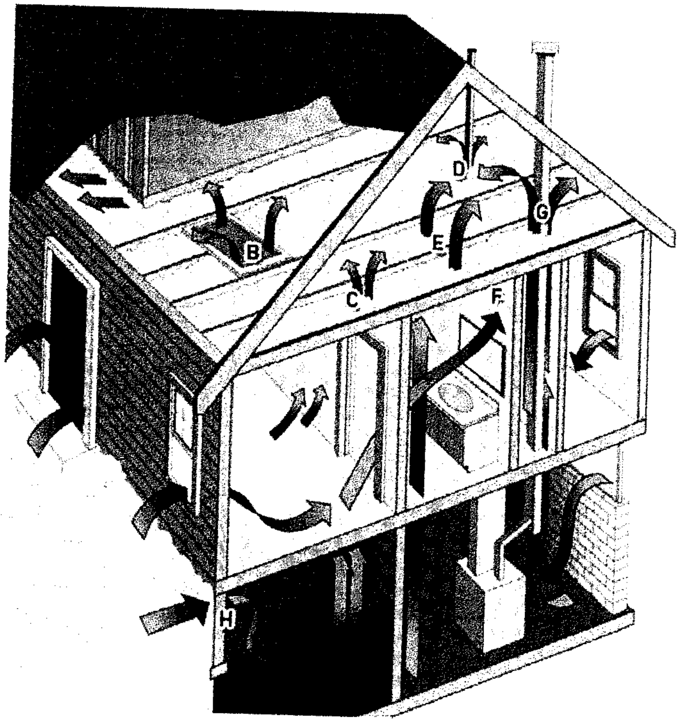
Reduce 30-100% of home's CO2 emissions by eliminating waste

Sick Home Symptoms

Comfort	Health	Efficiency
Too cold in the winter	Allergies	Increasing energy bills
Too hot in the summer	Mold or Moisture	Environmental concern

Building Science Basics

The driving forces behind building problems



Effects of Air Leaks

■ Cold outside air drawn into the house

▨ Heated inside air drawn into the attic

COMMON HOUSEHOLD AIR LEAKS

A - Between Floor Joists Behind Kneewalls
B - Attic Hatch
C - Wiring Holes
D - Plumbing Vent
E - Open Soffit (box hiding recessed lights)
F - Recessed Light
G - Furnace Flue or Duct Chaseways (hollow box/wall feature hiding ducts)
H - Basement Rim Joist (where foundation meets wood framing)

1. Heat Flow
2. Pressures
3. Moisture
4. Dew Point

Simple Concept – Heat Flow

- We study and track the transport of Air, Heat and Moisture with these principles
  - **Hot moves to cold**

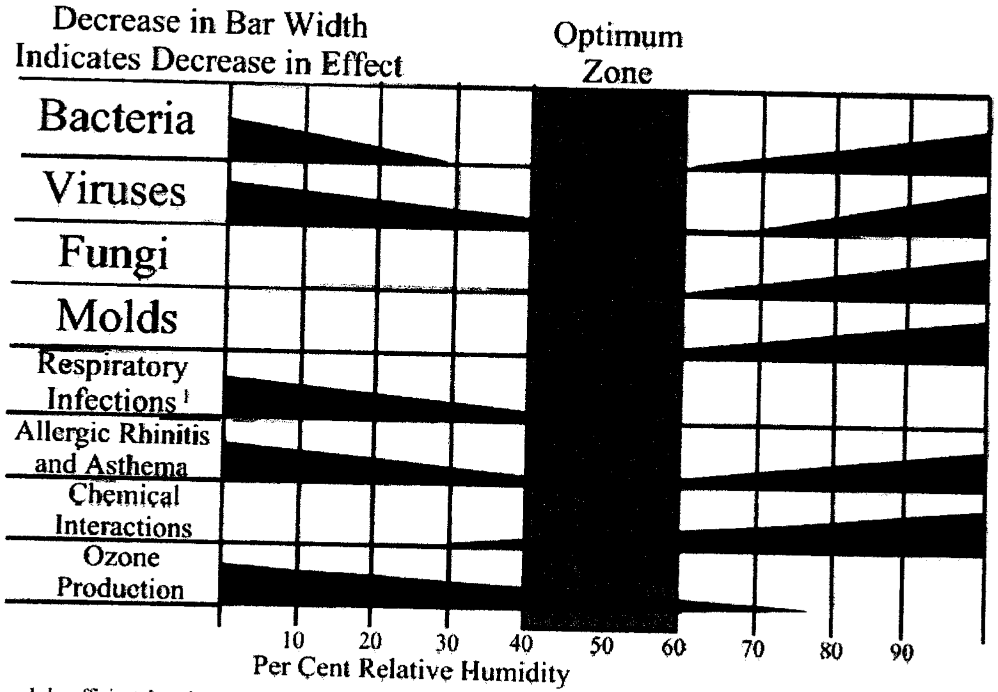
Heat Flow

- Forms of Heat Transfer
  - **Conduction** is the transfer of heat energy between objects that are in contact
    - touching a hot iron is one form of conduction
  - **Convection** is a mechanism for heat transfer in gases and liquids; it requires air or liquid movement to transfer heat
    - a hair dryer moves heat this way
  - **Radiation** is the transfer of heat in the infrared spectrum, and will occur even in the vacuum of space
    - how the sun's warmth reaches us

Simple Concept - Moisture

- We study and track the transport of Air, Heat and Moisture with these principles
  - Hot moves to cold
  - **Wet moves to dry**

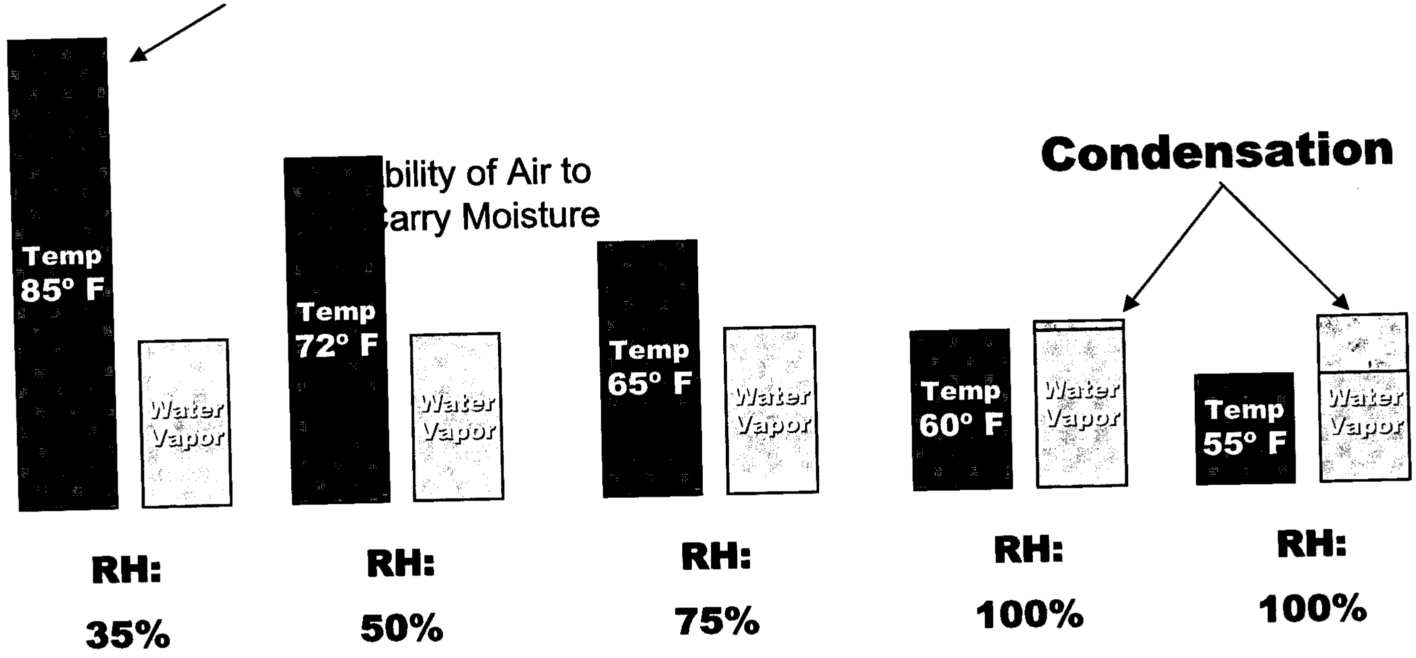
Relative Humidity



1. Insufficient data above 50% RH

Optimum Relative Humidity Ranges For Health
From "Criteria for Human Exposure to Humidity in Occupied Buildings"
Sterling, Arundel & Sterling ASHRAE Transactions, 1985, Vol 91, Part 1

Dewpoint and Temperature



Simple Concept - Pressure

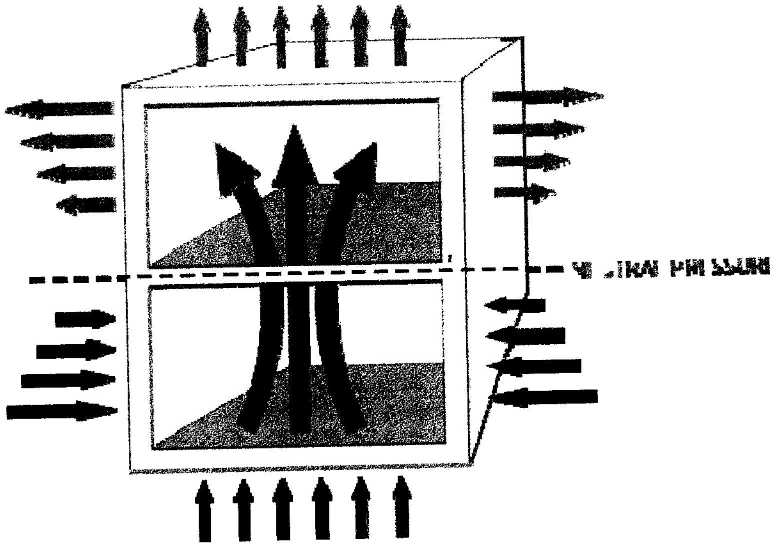
- We study and track the transport of Air, Heat and Moisture with these principles
  - Hot moves to cold
  - Wet moves to dry
  - **High pressure moves to low pressure**

Pressures

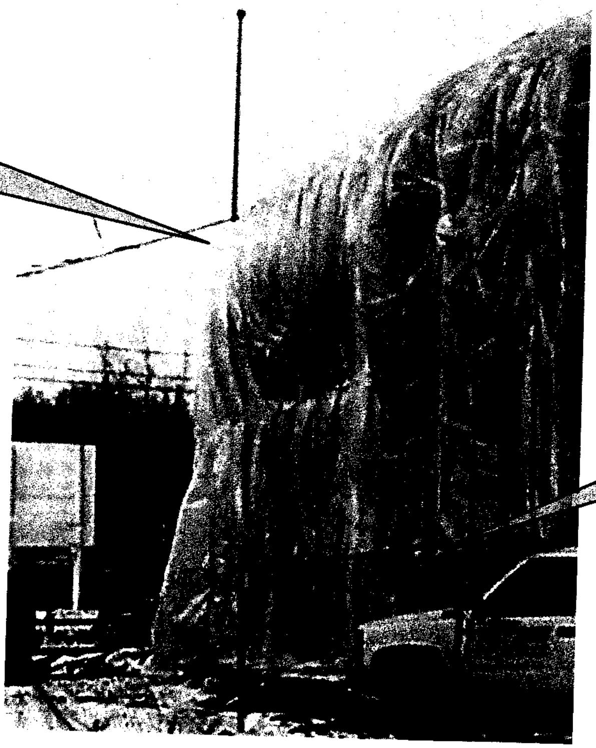
Driving Forces:

- <u>Stack Effect</u> – the taller the building, the more pronounced the stack effect.
- <u>Wind Effect</u> – wind creates a positive pressure on the windward side of the building and a negative pressure on the leeward side of the building.
- <u>Mechanical Systems</u> – Fans, HVAC

STACK EFFECT IN A
TWO STORY HOUSE



Stack Effect



High Pressure
Pushes Plastic
Out...

Low Pressure
Sucks Plastic
in...

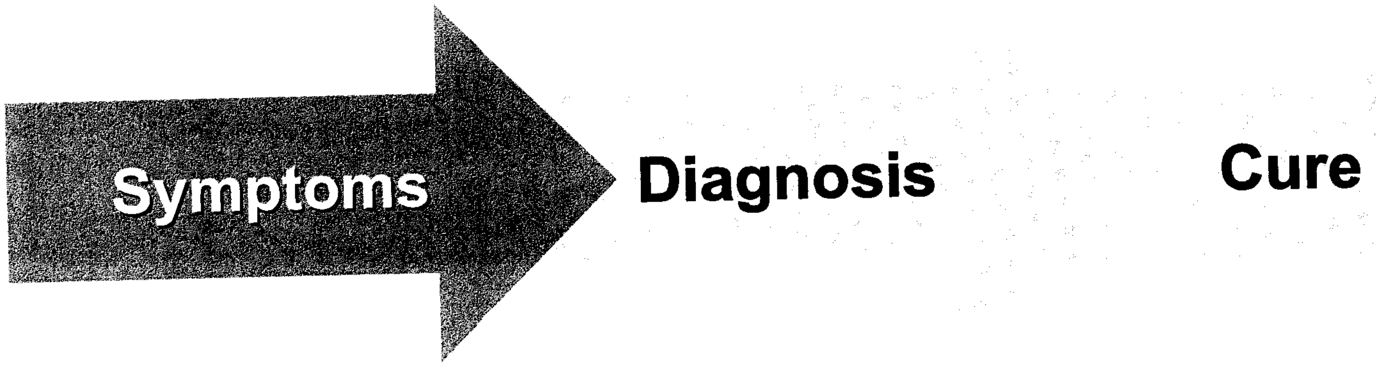
Key Concept – Building Envelope

House as a System

It All Works Together!

- *Insulation*
- *Ducts*
- *HVAC Equipment*
- *Building Shell*
- *Windows & Doors*
- *Combustion Safety*
- *Water Heating*
- *Appliances & Lighting*

The Process



Symptoms

Diagnosis

Cure

Home Performance Testing

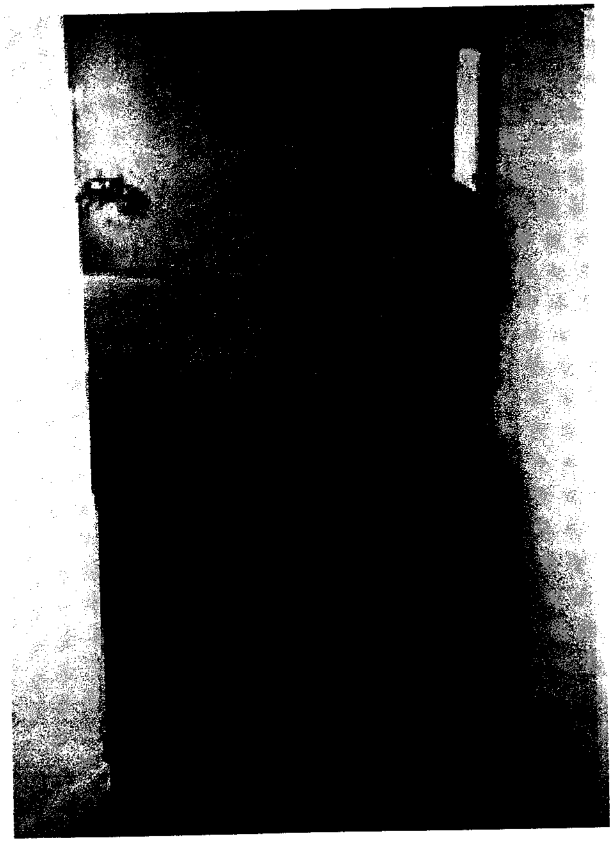
Testing Methods

Blower Door Test

Duct Blaster Test

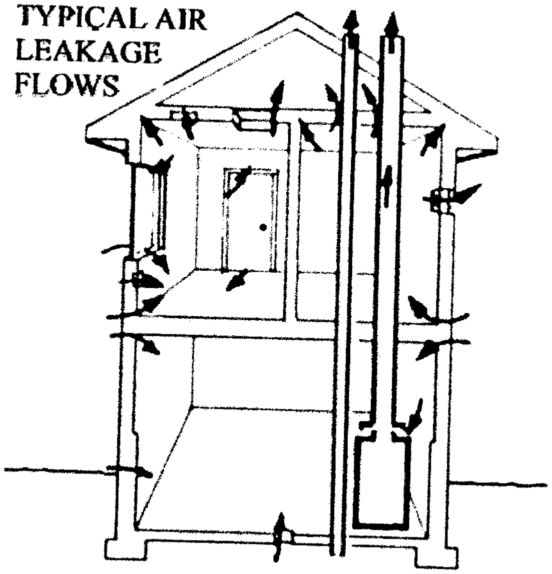
Infrared T[illegible]rmography

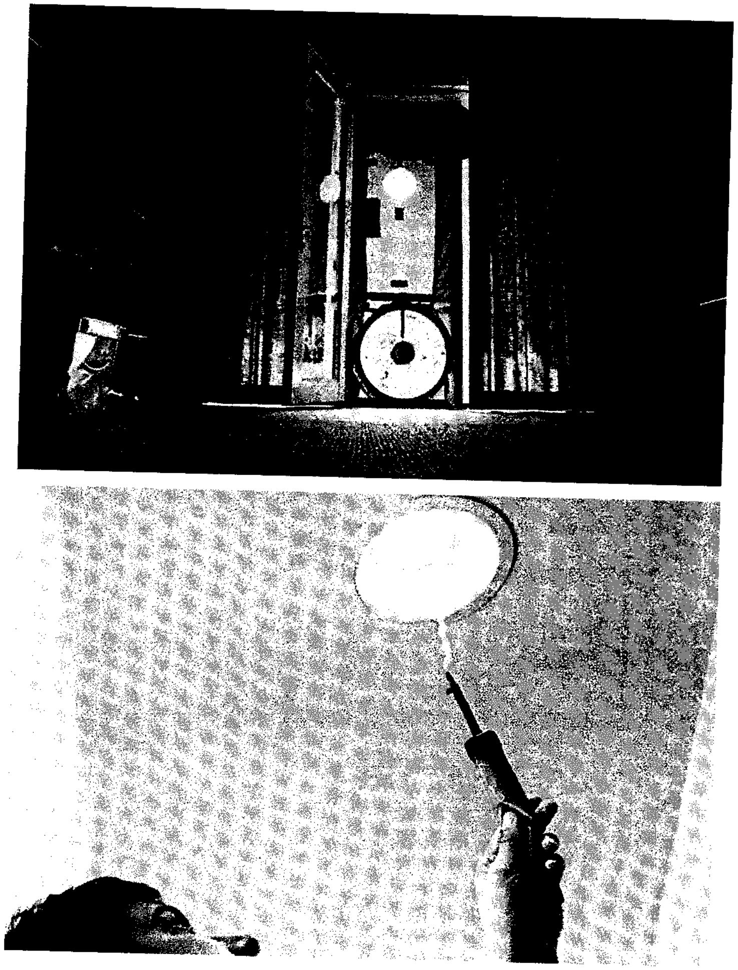
Fan Watt Draw Test



Blower Door

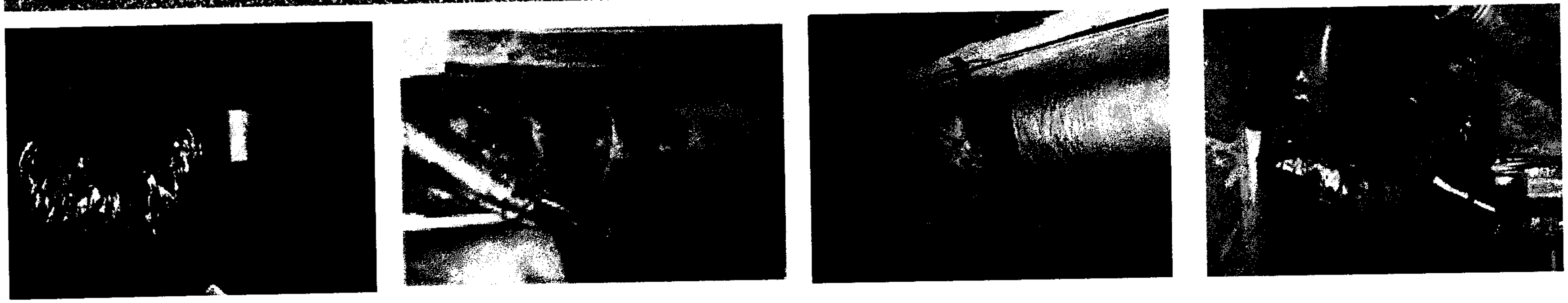
- Measure Air Leakage
- Find Infiltration Points



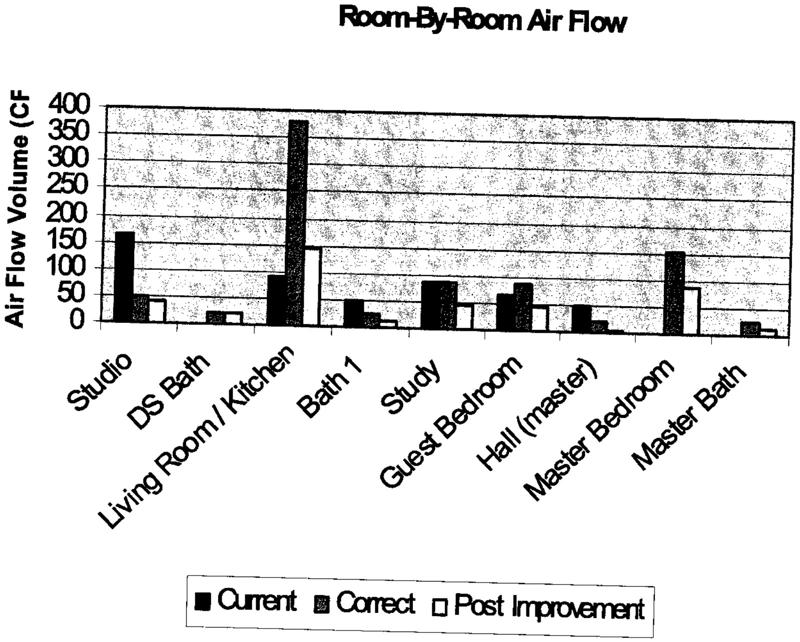


Duct Blaster

- Measure Duct Leakage
- California Average 30% Leakage!

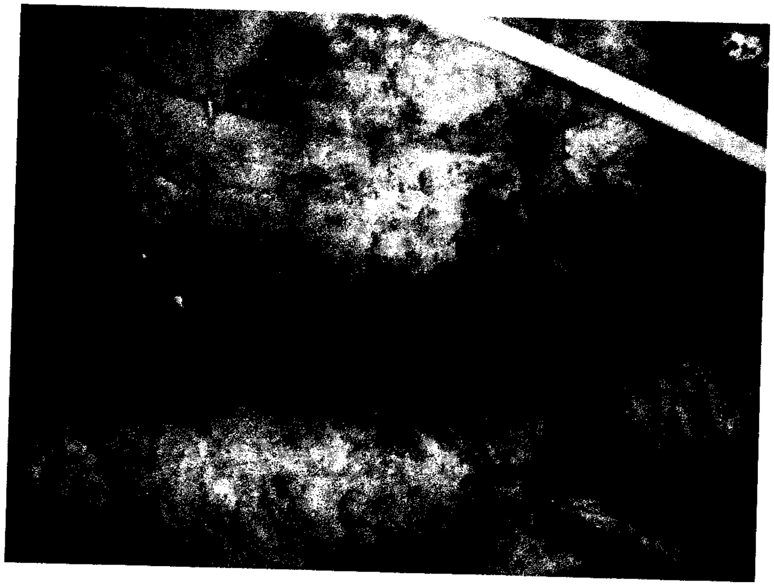


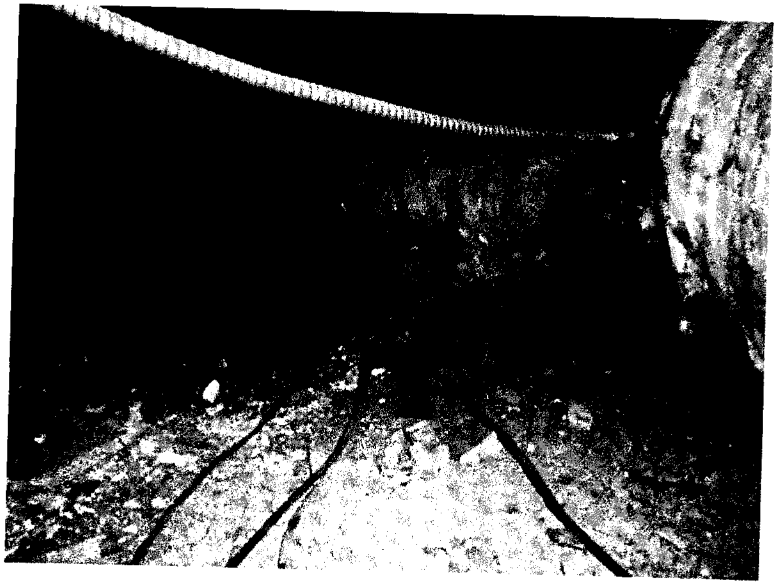
Air Balancing



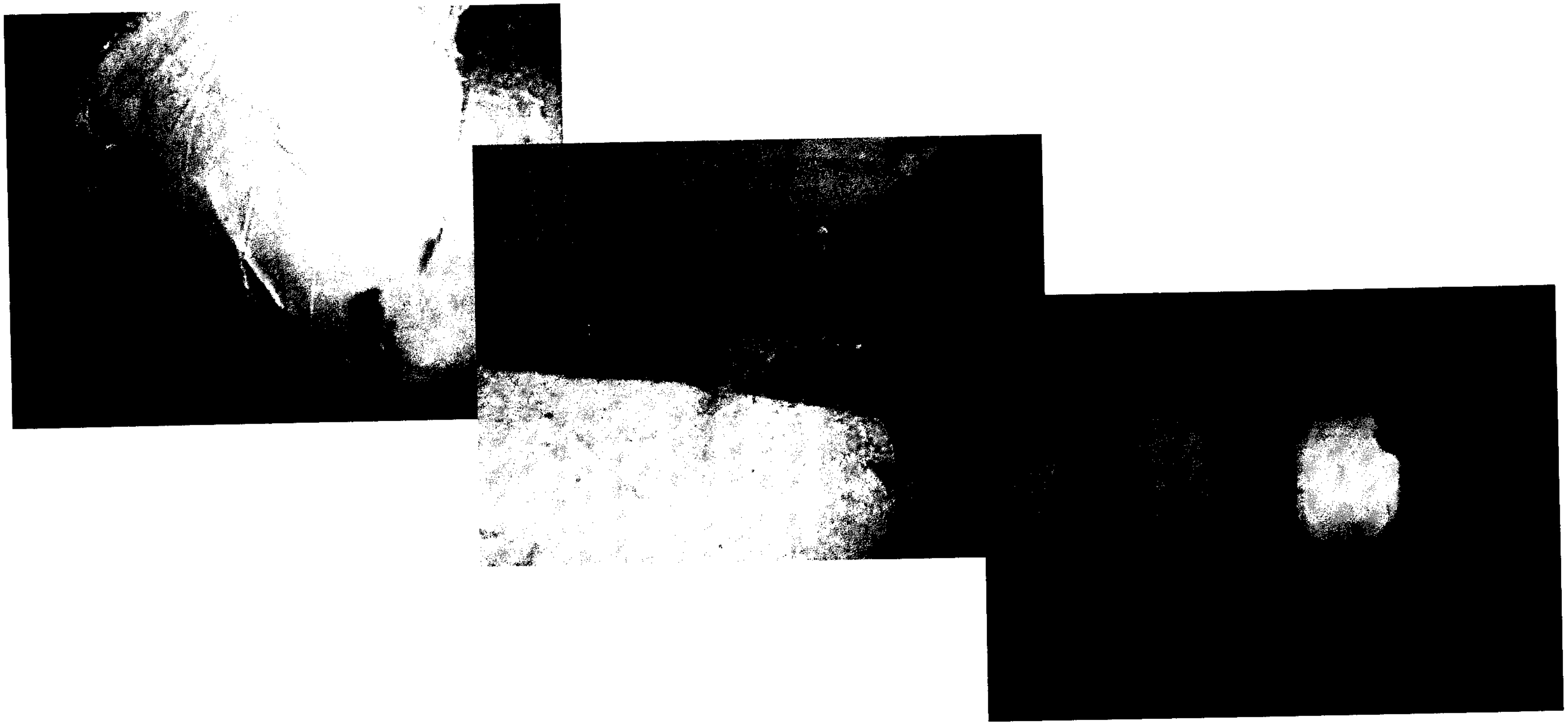
Infrared Analysis

Duct Inspection

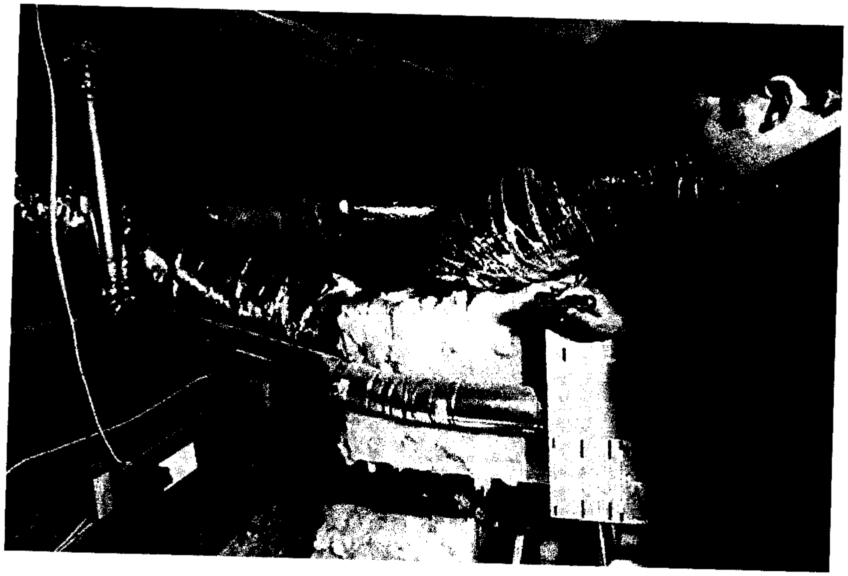




Duct Inspection

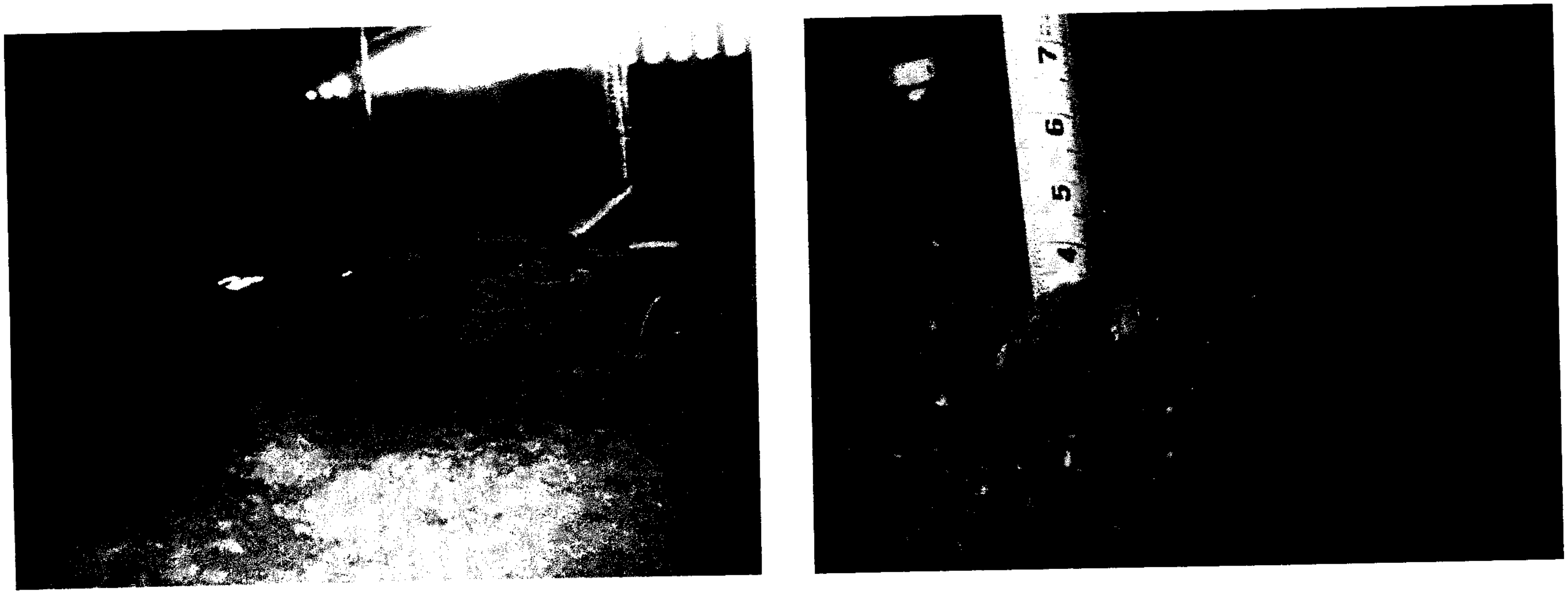


Combustion Testing

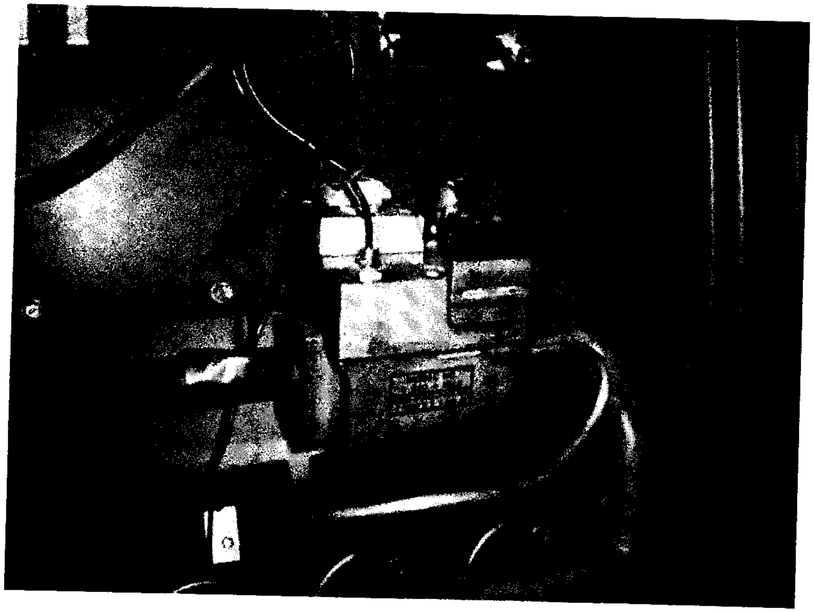


- Test Combustion Efficiency
- Test Flue Systems
- Check Carbon Monoxide

Attic Inspection

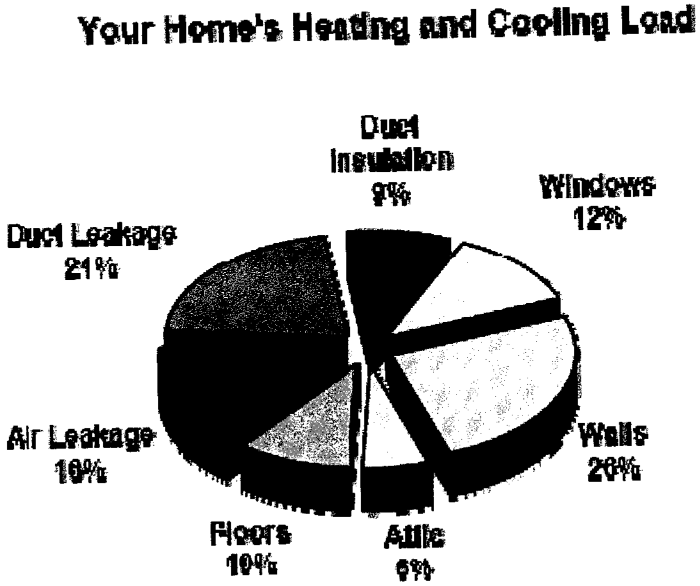


Furnace Inspection



Energy Modeling

- Know what you will save



Bill Analysis

Use to determine baseload and seasonal variations
Can often infer specific appliance usage

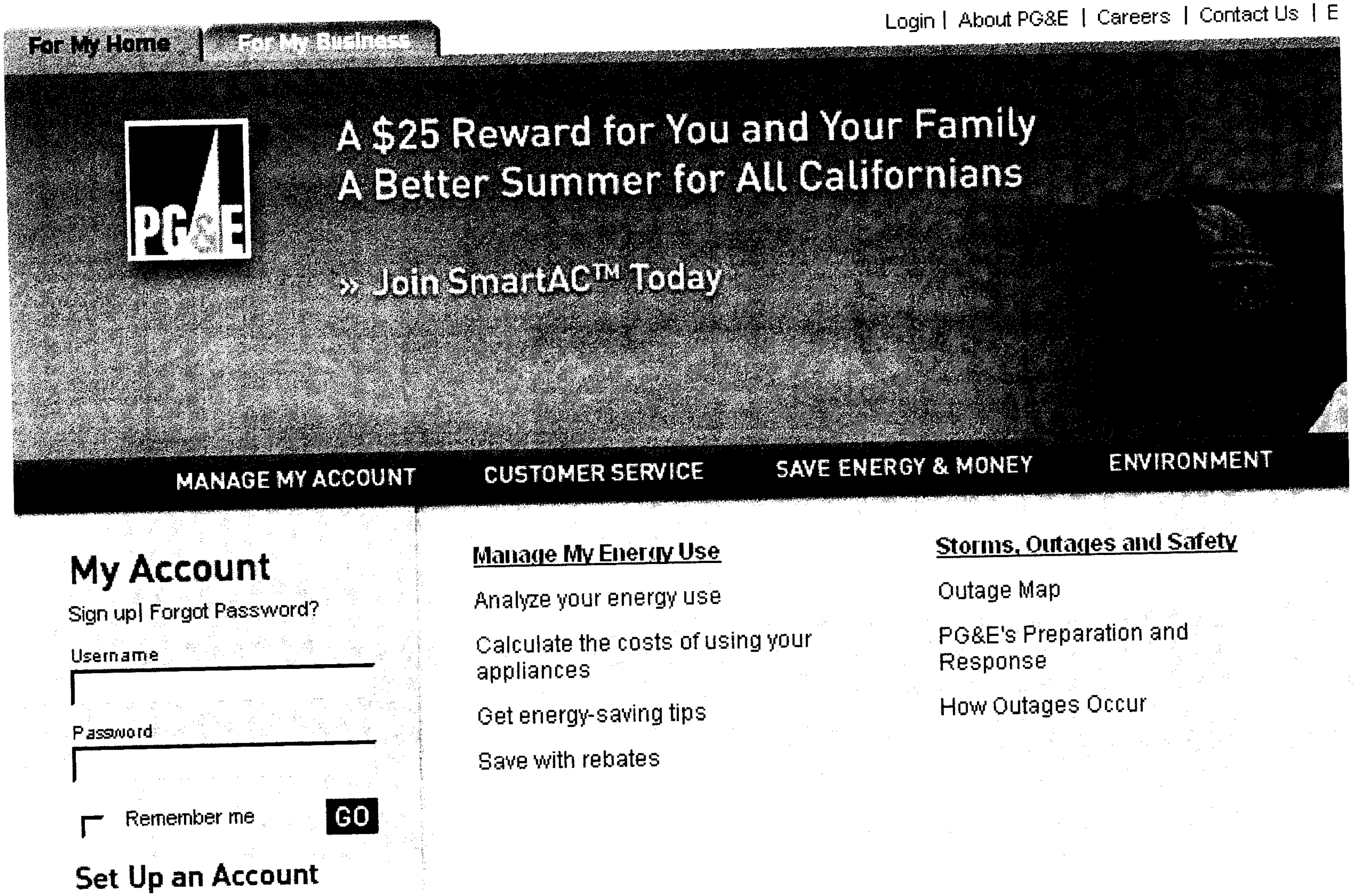
Process:

- Get at least full year data
- Check for unusual situations (shut down, vacation)
- Take 3 lowest months, toss out the smallest, average other two
- Same process for highest months

Best Way:

- Establish online account wth PG&E

For My Home



A $25 Reward for You and Your Family
A Better Summer for All Californians

» Join SmartAC™ Today

My Account

Sign up | Forgot Password?

Username

Password

☐ Remember me

Set Up an Account

Manage My Energy Use

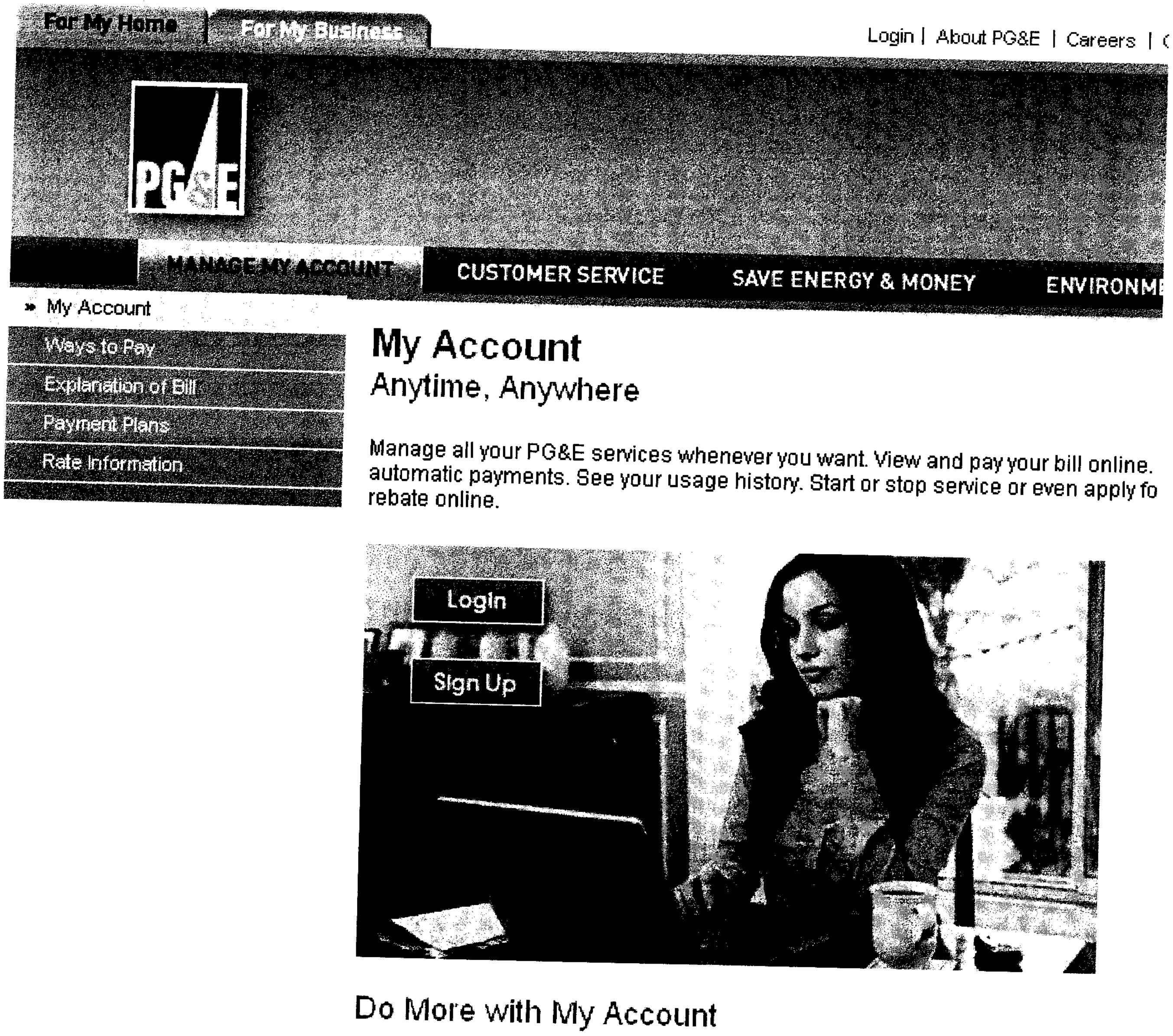
- Analyze your energy use
- Calculate the costs of using your appliances
- Get energy-saving tips
- Save with rebates

Storms, Outages and Safety

- Outage Map
- PG&E's Preparation and Response
- How Outages Occur

PG&E website: www.pge.com

Establish Online Account



My Account

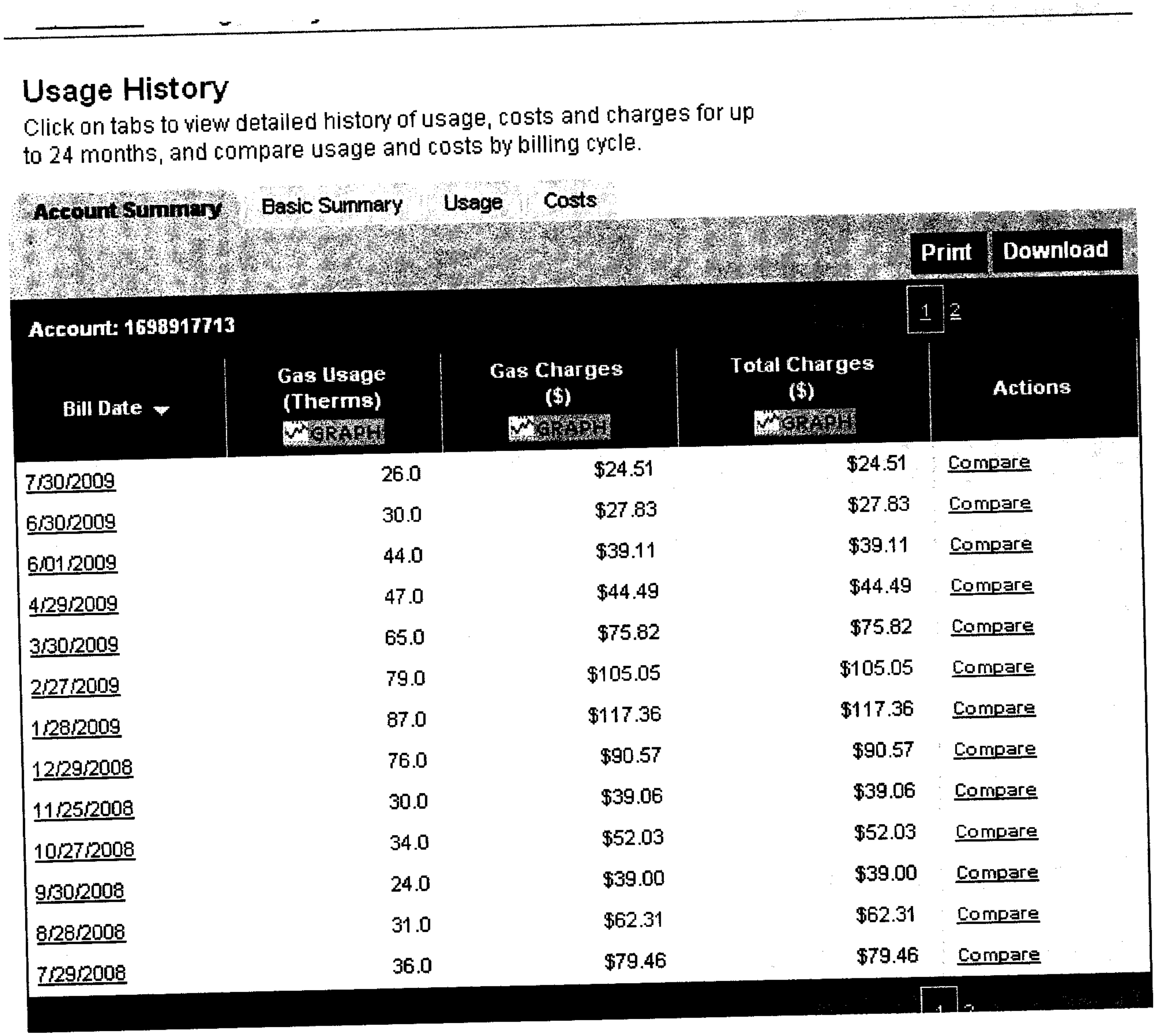
Anytime, Anywhere

Manage all your PG&E services whenever you want. View and pay your bill online. automatic payments. See your usage history. Start or stop service or even apply fo rebate online.

Do More with My Account

PG&E website: www.pge.com

Get Usage History



Usage History

Click on tabs to view detailed history of usage, costs and charges for up to 24 months, and compare usage and costs by billing cycle.

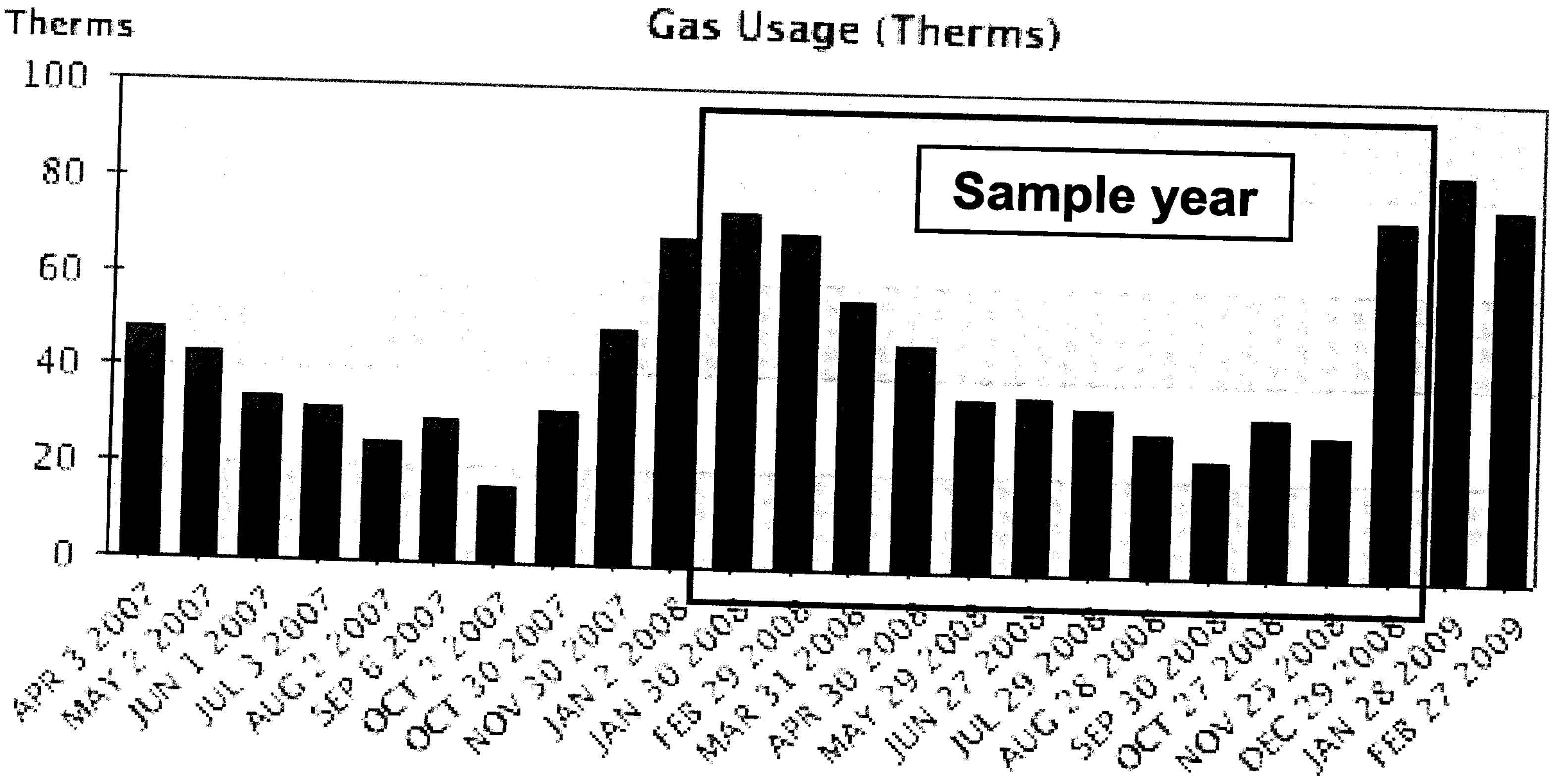
Account: 1698917713

Bill Date	Gas Usage (Therms)	Gas Charges ($)	Total Charges ($)	Actions
7/30/2009	26.0	$24.51	$24.51	Compare
6/30/2009	30.0	$27.83	$27.83	Compare
6/01/2009	44.0	$39.11	$39.11	Compare
4/29/2009	47.0	$44.49	$44.49	Compare
3/30/2009	65.0	$75.82	$75.82	Compare
2/27/2009	79.0	$105.05	$105.05	Compare
1/28/2009	87.0	$117.36	$117.36	Compare
12/29/2008	76.0	$90.57	$90.57	Compare
11/25/2008	30.0	$39.06	$39.06	Compare
10/27/2008	34.0	$52.03	$52.03	Compare
9/30/2008	24.0	$39.00	$39.00	Compare
8/28/2008	31.0	$62.31	$62.31	Compare
7/29/2008	36.0	$79.46	$79.46	Compare

PG&E website: www.pge.com

Bill Analysis: Gas

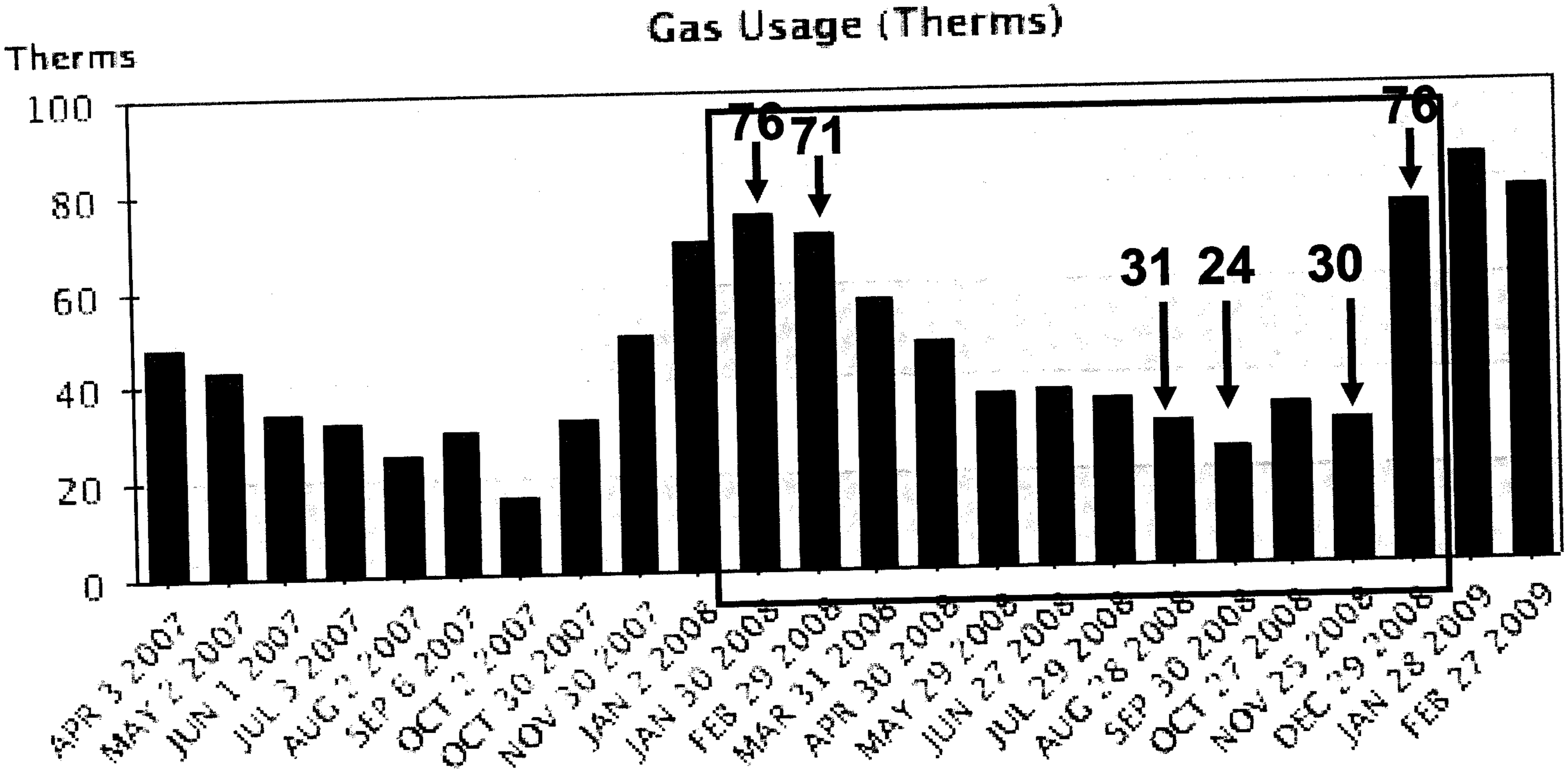
Home #1: Single family home, California coast
1800 sf, 3 people.
Gas water heater, space heater, stove & oven.



Source: PG&E

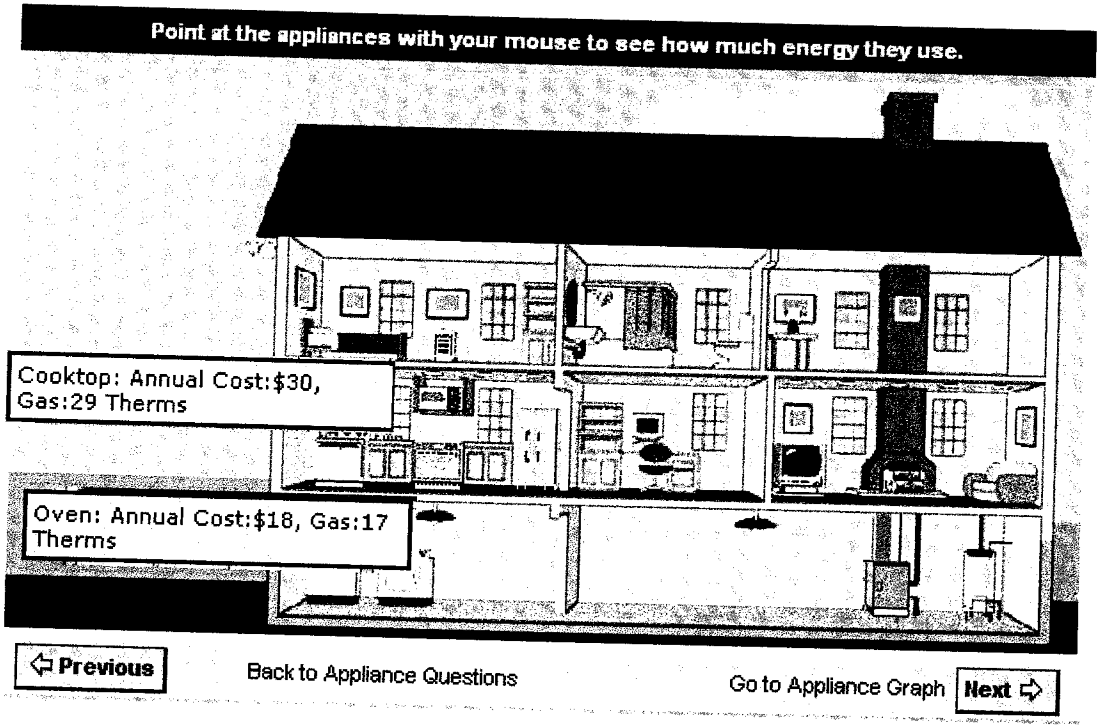
Bill Analysis: Gas

3 lowest: ~~24,~~ 31, 30 – avg. 30.5
3 highest: ~~76,~~ 76, 71 – avg. 73.5



Bill Analysis: Gas

Estimate other usage from PG&E analyzer.



Point at the appliances with your mouse to see how much energy they use.

Cooktop: Annual Cost:$30, Gas:29 Therms

Oven: Annual Cost:$18, Gas:17 Therms

Total oven & stove = 29 + 17 = 46/year = 4/month

Lowest total = 30 – 4 = 26 - 5 (some heating year round) = about 20 therms/month for hot water

Bill Analysis: Gas

Home #1 Gas Yearly Estimate:

Exact total (usage history) = 558 therms

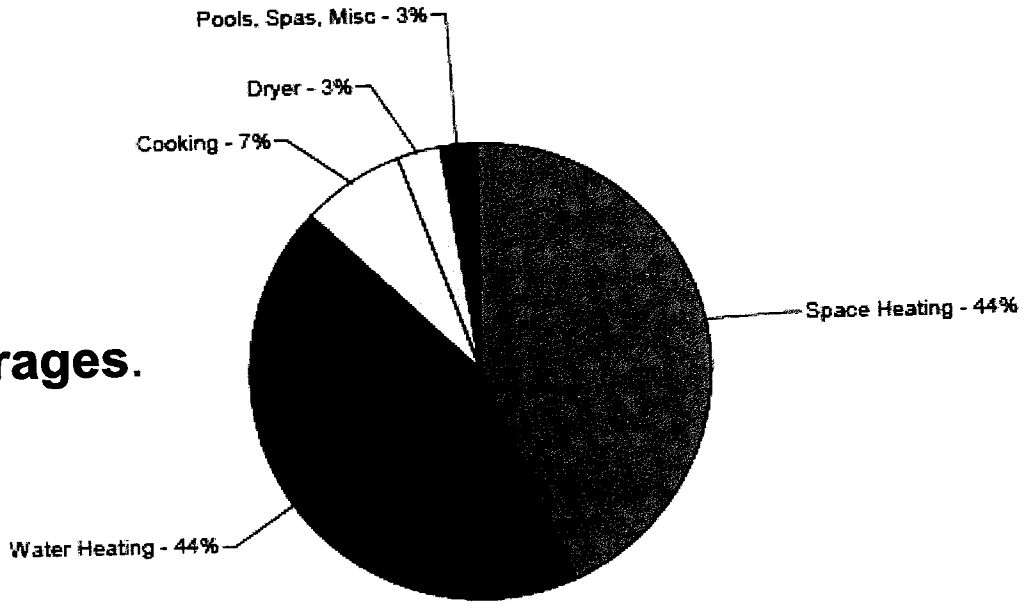
Est. hot water = 240 therms

Est. Stove & Oven = 46 therms

Est. heating (remainder) = 272 therms

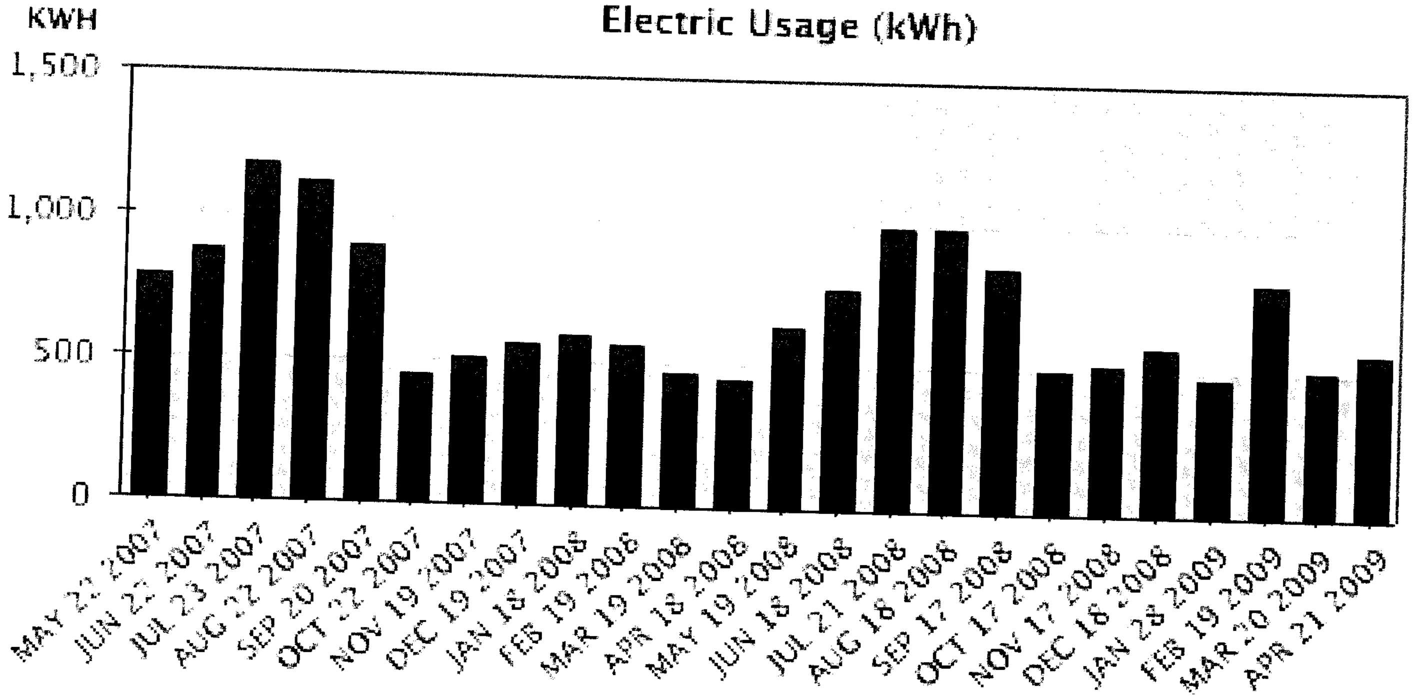
Corresponds to statewide averages.

Figure 5
Statewide Gas Energy Use



Bill Analysis: Electric

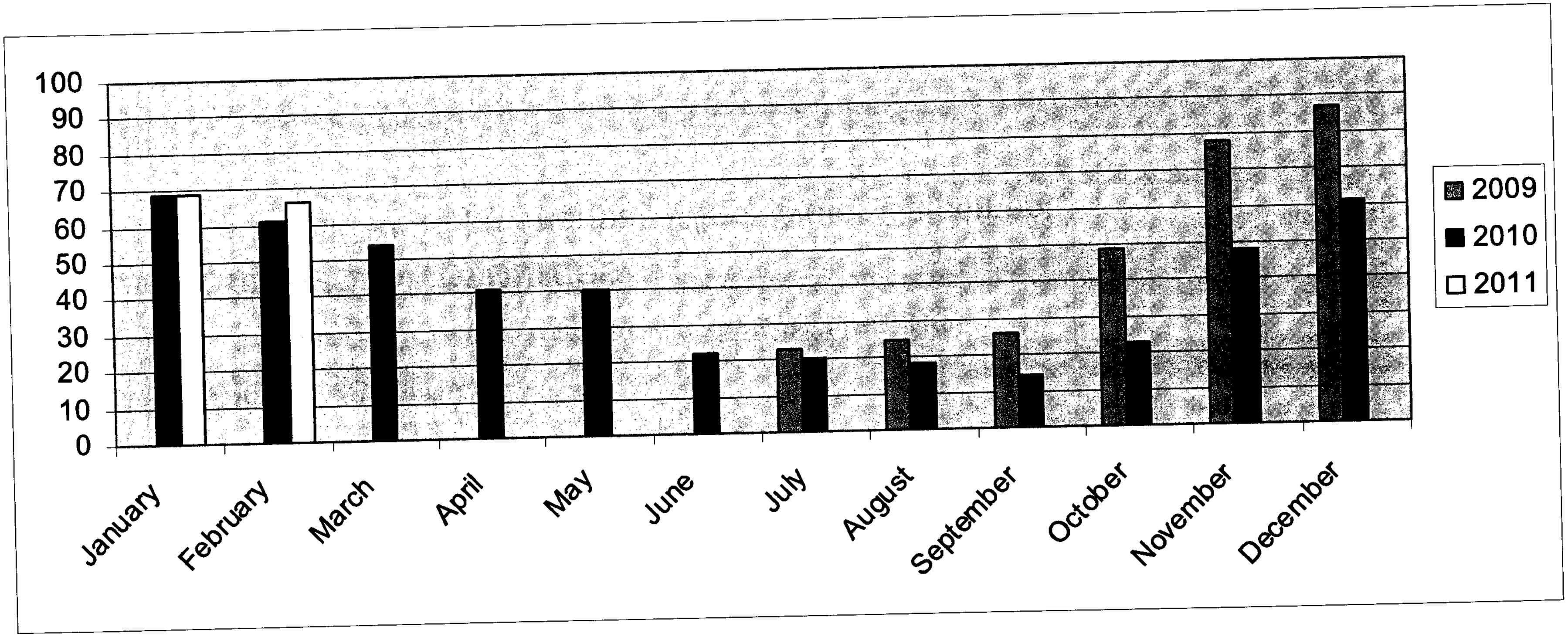
Home #2: Single family home, Central Valley
2200 sf, 4 people.
Electric air conditioning.



Opposite cycle from gas usage.

Source: PG&E

Typical
Gas Usage



Home Efficiency Roadmap

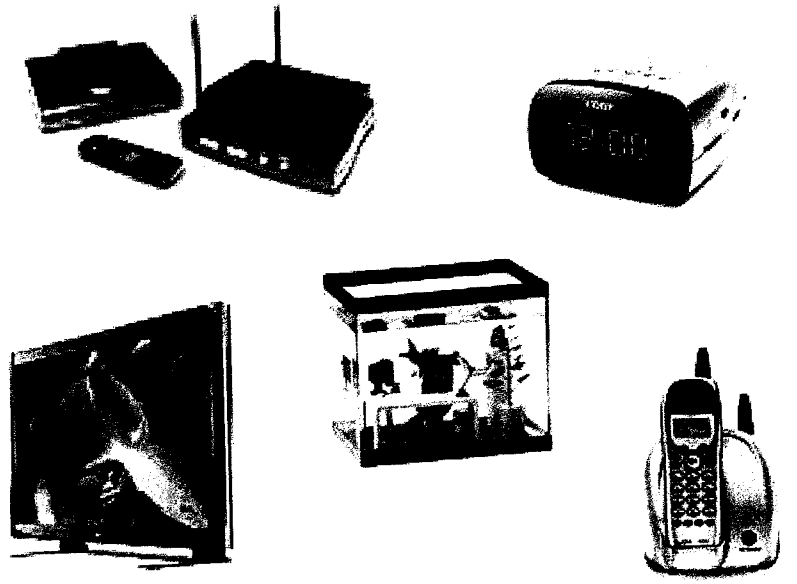
1. Building Fundamentals
    - Insulation, Ducts, Air Leakage, Water Conservation, Moisture Management, Lighting, Appliances, Plug Loads
2. Major Systems
    - Heating, Cooling, Ventilation, Water Heating
3. Renewable Resources
    - Solar PV, Solar Thermal, Wind, Water Catchment

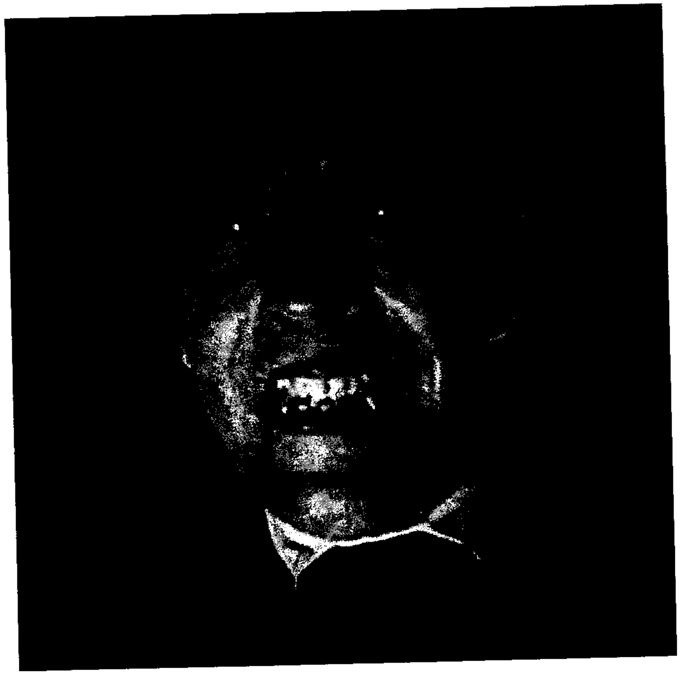
Plug Loads

Appliances that draw power 24/7

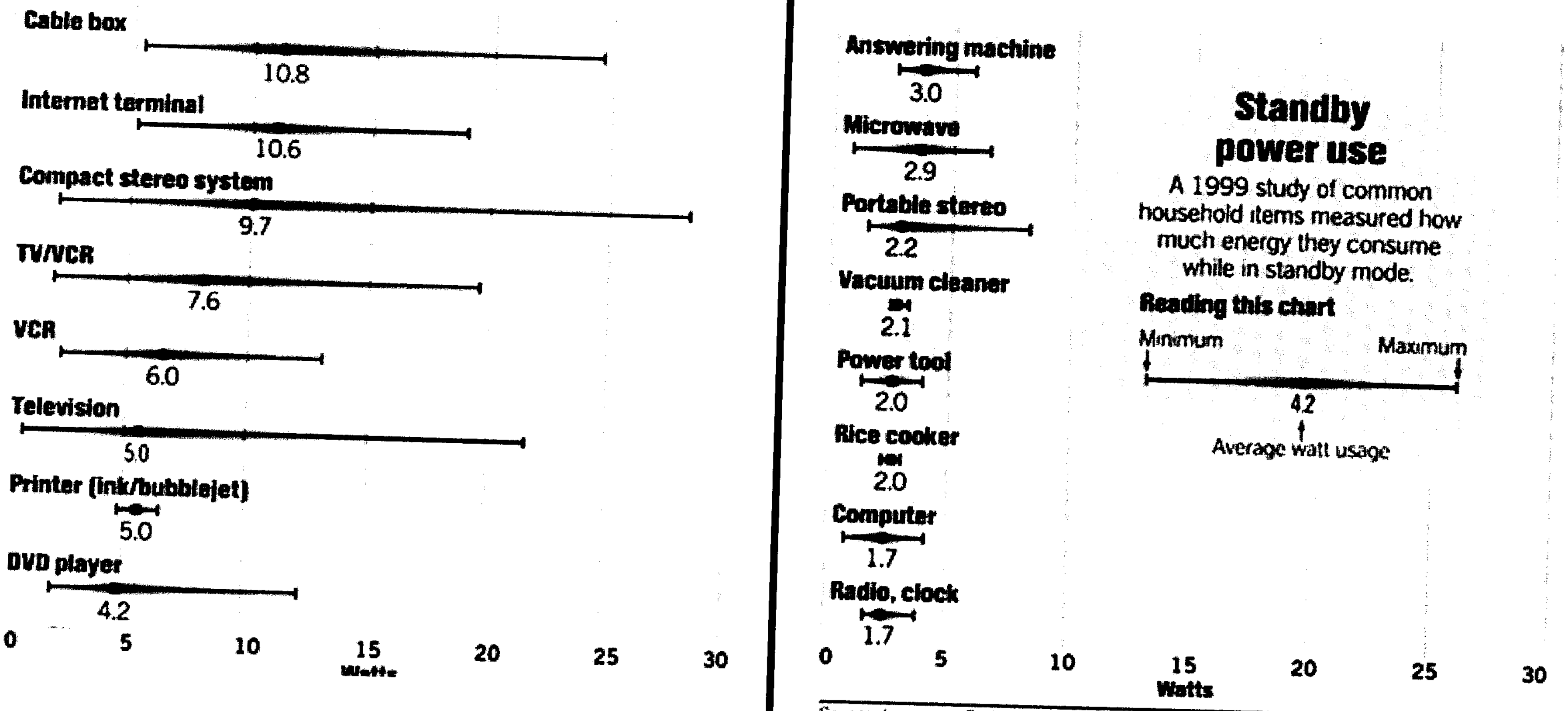
Never off even when they’re “off”

Large increase—growing problem





VAMPIRE LOADS



Standby power use

A 1999 study of common household items measured how much energy they consume while in standby mode.

Source: Lawrence Berkeley National Laboratory

The Chronicle

VAMPIRE LOADS

- TV <1 to 50+ w) Cable Box (20+ w)
- ANYTHING WITH A REMOTE (1 to 5 w)
- BATTERY CHARGERS (1 or 2 watts)
- MODEM (5+ w)
- ROUTER (5+ w) (2+ INTERNET CONNECTIONS)
- FISH TANK PUMP (2 to 3 w 10 gal tank)
- HANDS FREE PHONE BASE (3+ w)
- PLUGGED IN CLOCKS (<1 to 5 watts)
  (MICROWAVE/STOVE/CLOCK RADIOS/VCR/ETC)

VAMPIRE LOADS

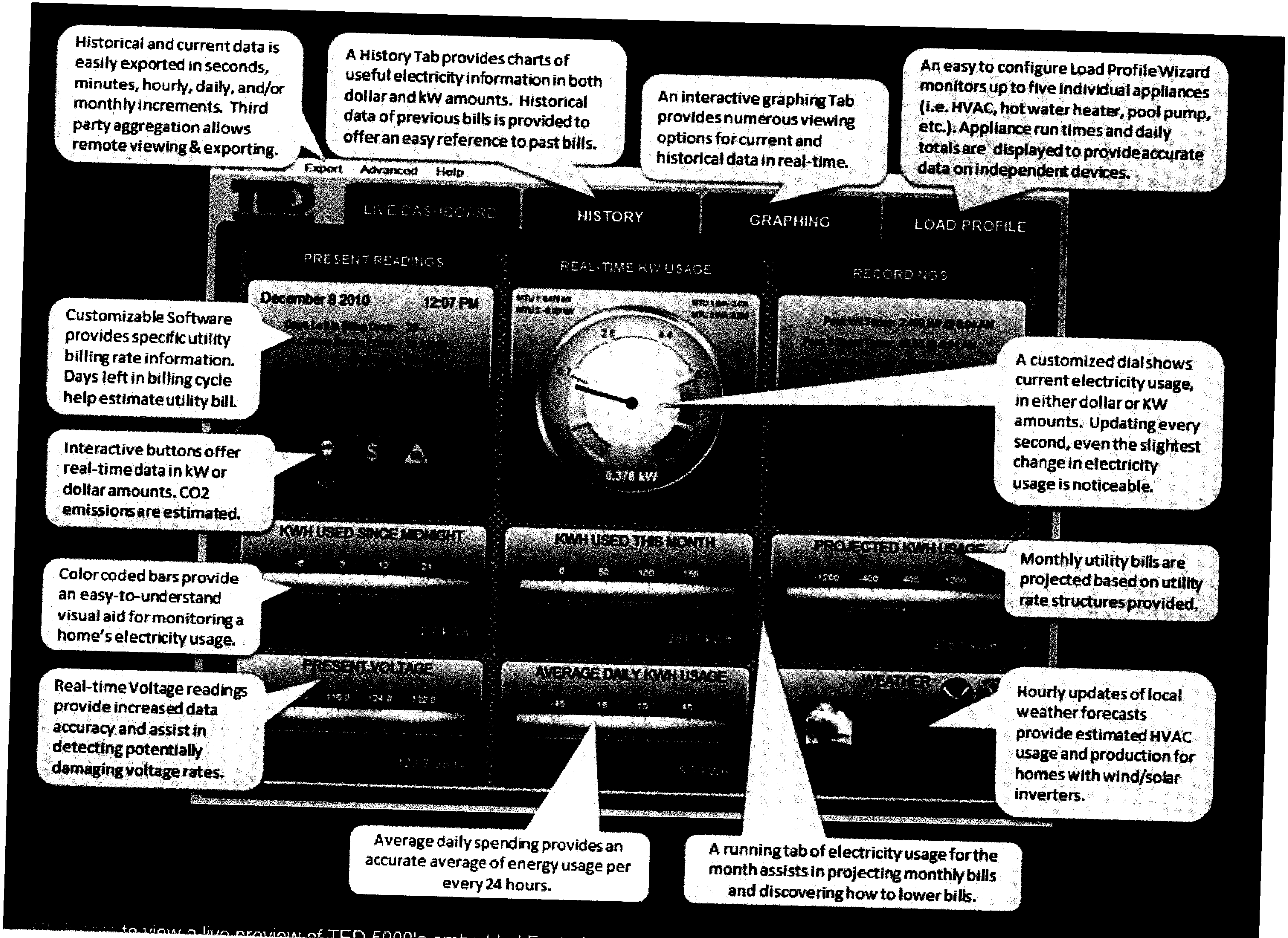
- TV: 30w X 2 = 60w
- Cable Box: 20w X 2 = 40w
- Remotes: 3w x 5 = 15w
- Modem: 7w
- Router: 7w
- Fish Tank Pump: 3w
- Phone: 3w
- Clocks: 3w X 5 = 15w

Total = 150 watts x 8760 hrs/yr = 1,300 kWh/yr
At $.18/kwh (avg.) = $234/yr.

Plug Loads

Solutions:

- Power strips
- "Smart" strips (master/slave)
- Timers
- Turn things off when not in use



Historical and current data is easily exported in seconds, minutes, hourly, daily, and/or monthly increments. Third party aggregation allows remote viewing & exporting.

A History Tab provides charts of useful electricity information in both dollar and kW amounts. Historical data of previous bills is provided to offer an easy reference to past bills.

An interactive graphing Tab provides numerous viewing options for current and historical data in real-time.

An easy to configure Load Profile Wizard monitors up to five individual appliances (i.e. HVAC, hot water heater, pool pump, etc.). Appliance run times and daily totals are displayed to provide accurate data on independent devices.

Customizable Software provides specific utility billing rate information. Days left in billing cycle help estimate utility bill.

Interactive buttons offer real-time data in kW or dollar amounts. CO2 emissions are estimated.

A customized dial shows current electricity usage, in either dollar or KW amounts. Updating every second, even the slightest change in electricity usage is noticeable.

Color coded bars provide an easy-to-understand visual aid for monitoring a home's electricity usage.

Monthly utility bills are projected based on utility rate structures provided.

Real-time Voltage readings provide increased data accuracy and assist in detecting potentially damaging voltage rates.

Hourly updates of local weather forecasts provide estimated HVAC usage and production for homes with wind/solar inverters.

Average daily spending provides an accurate average of energy usage per every 24 hours.

A running tab of electricity usage for the month assists in projecting monthly bills and discovering how to lower bills.

to view a live preview of TED 5000's embedded Footprints software running in real-time. The link will give you a live connection to

Track energy over time

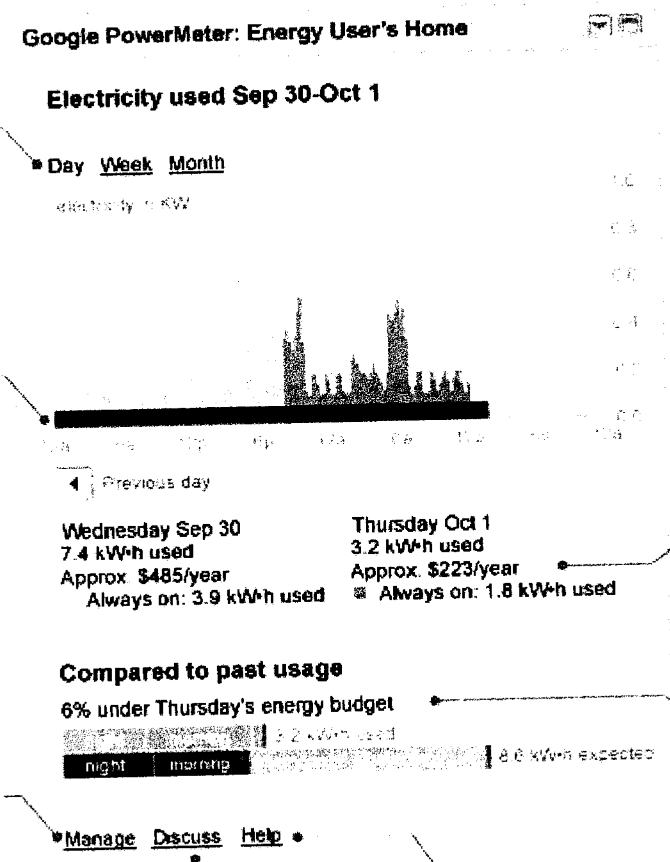
See how much energy you have used by the day, week or month.

Always on power

The darker shaded portion of the graph shows power that is always on, such as any appliance that goes on standby mode. Many appliances are always on; you just don't know it. Discovering these is one of the easiest and fastest ways to reduce energy use and save money.

Customize your experience

Add your estimated cost per kWh, sign up for weekly emails, and share your usage with family and friends.



Google PowerMeter: Energy User's Home

Electricity used Sep 30-Oct 1

● Day Week Month

◀ Previous day

Wednesday Sep 30
7.4 kWh used
Approx. $485/year
Always on: 3.9 kWh used

Thursday Oct 1
3.2 kWh used
Approx. $223/year
▨ Always on: 1.8 kWh used

Compared to past usage

6% under Thursday's energy budget

Manage Discuss Help

Predict your costs

Google PowerMeter helps you to predict your annual energy bill so that you can start making changes and saving early.

Budget Tracker

Set an energy savings goal for yourself and track your progress.

Join the community

Get tips on how to save from other Google PowerMeter users and share what has worked for you.

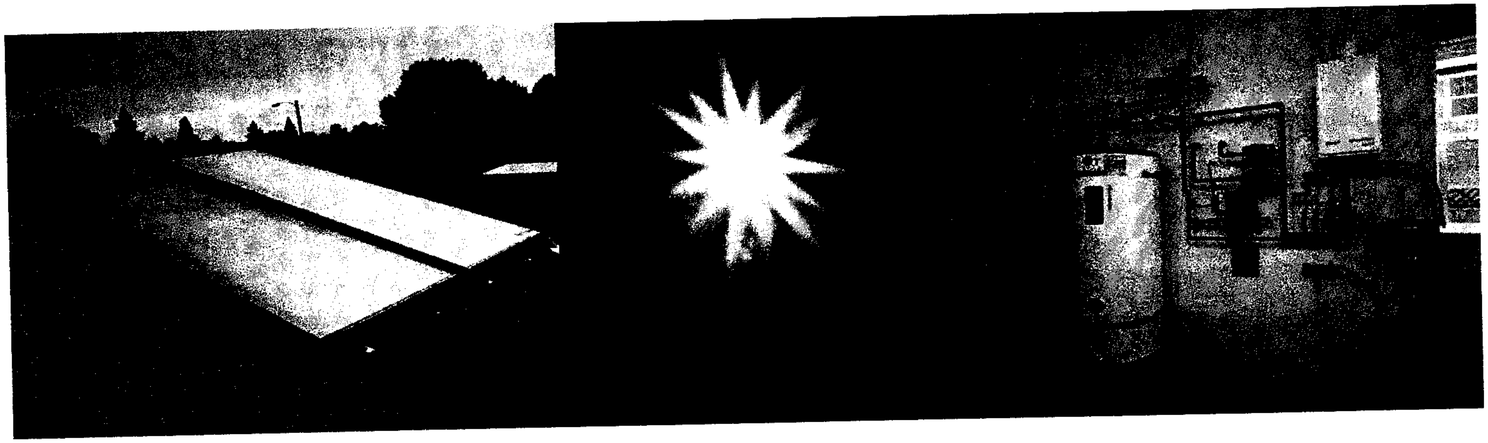
Have a question?

Learn more about Google PowerMeter from our online help center.

Potential Conservation Measures

- Sealing or Replacing Ducts
- Weatherizing Openings
- Window Replacements/Refurbishment
- Insulation (under, attic, walls)
- Programmable Thermostats
- Tankless Water-heaters
- Photovoltaics, Solar Thermal
- Lighting Retrofits

Water Heating

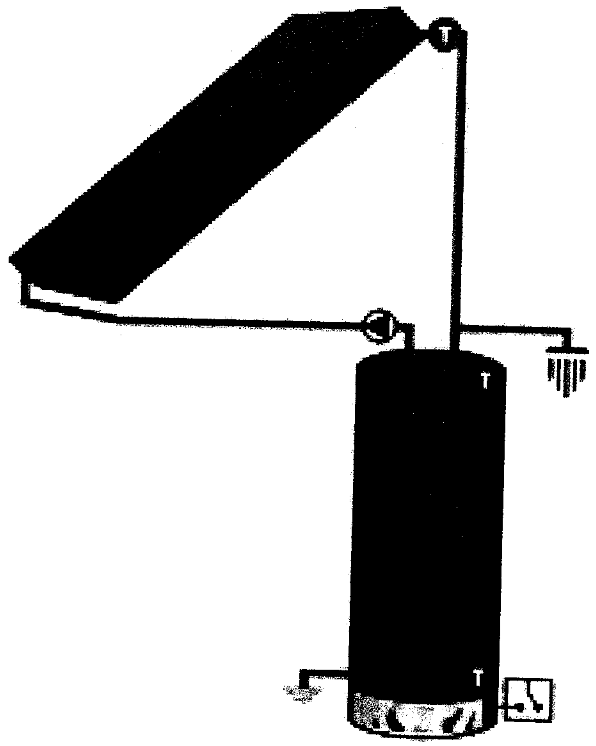


Courtesy of DOE/NREL

Solar Water Heating

SWH always has backup heater, either gas or electric.

Efficiency of backup heater and entire system is crucial to economics, even more so than with PV.



Courtesy Heliodyne

Standard Water Heaters

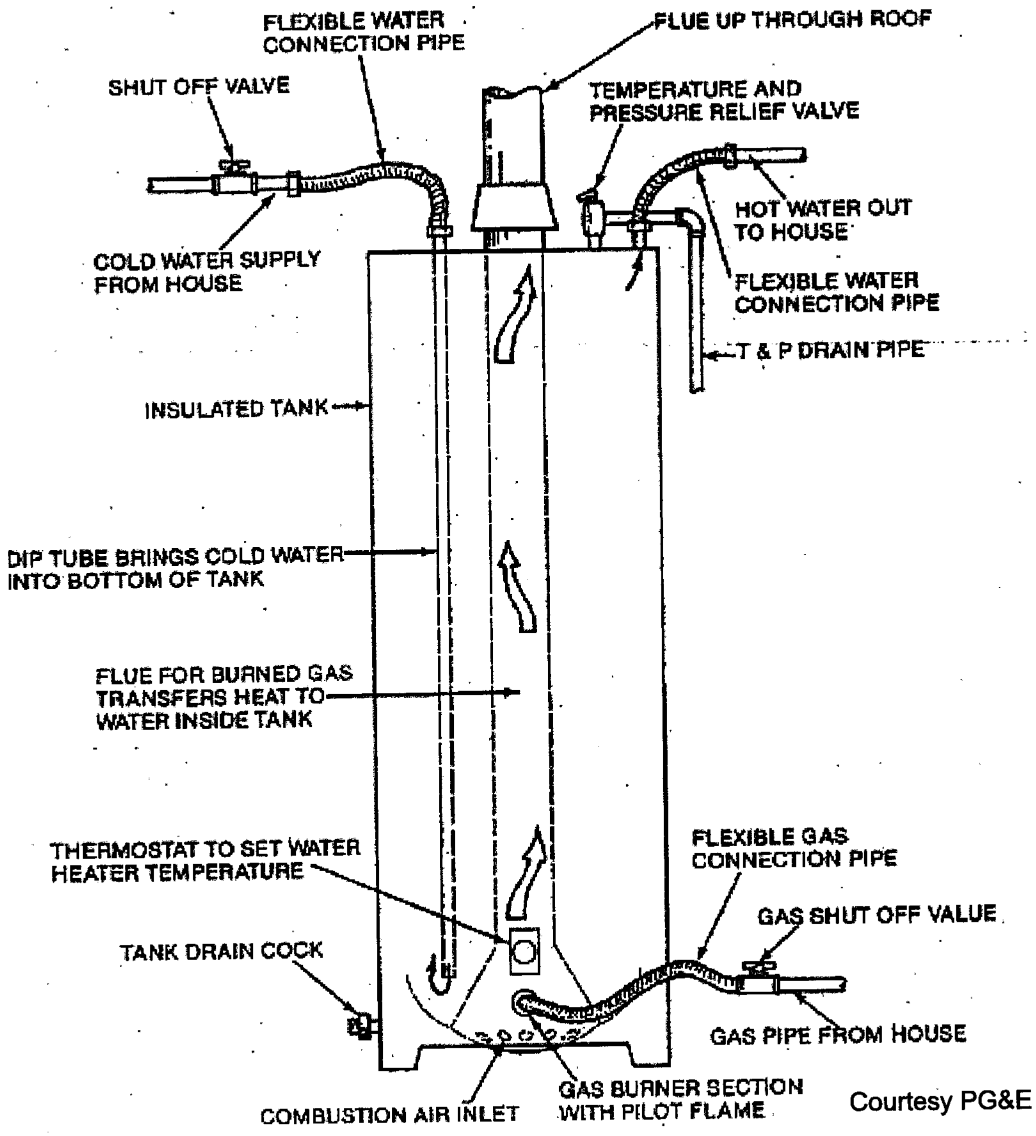
Typical gas heater:

Direct flue.

Much heat loss "up the chimney".

Low efficiency.

(50 – 70%)



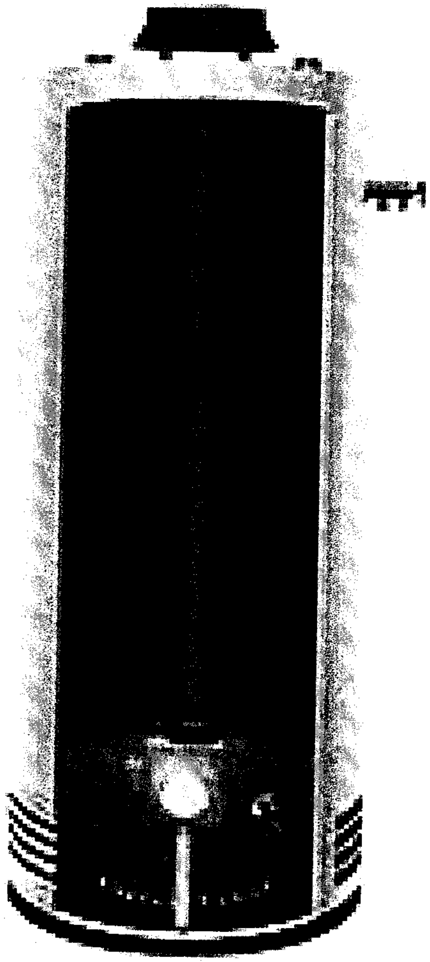
Courtesy PG&E

Standard Water Heaters

Improved model:

Same basic technology, better insulation.

Efficiency around 70 – 80%.



Source: Energy Star

Standard Water Heaters

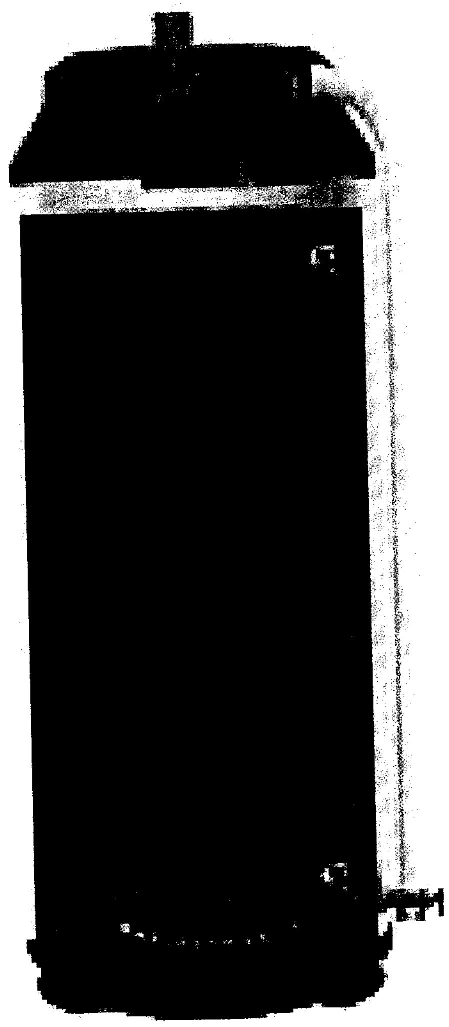
More improved model:

Condensing heater.

Extended flue which releases much of its heat to the water before venting.

Vent gases are cool enough to condense.

Efficiency around 80 – 90+%



Source: Energy Star

Standard Water Heaters

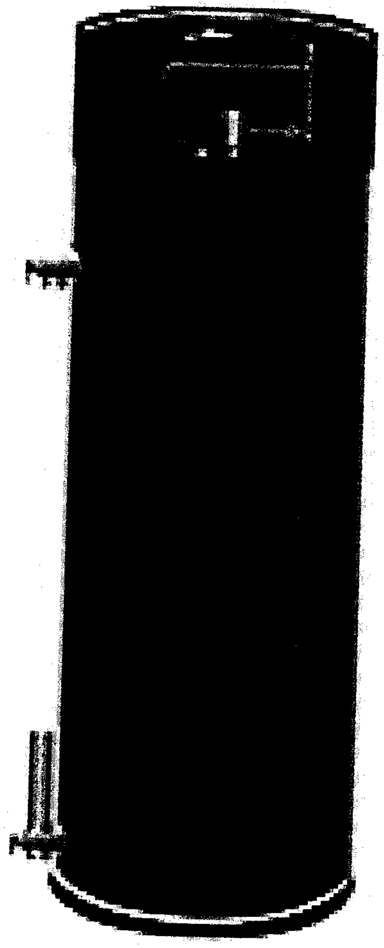
New model:

Heat pump.

Like refrigerator in reverse.

Electric powered, no gas burning.

Best to replace electric water heater.



Source: Energy Star

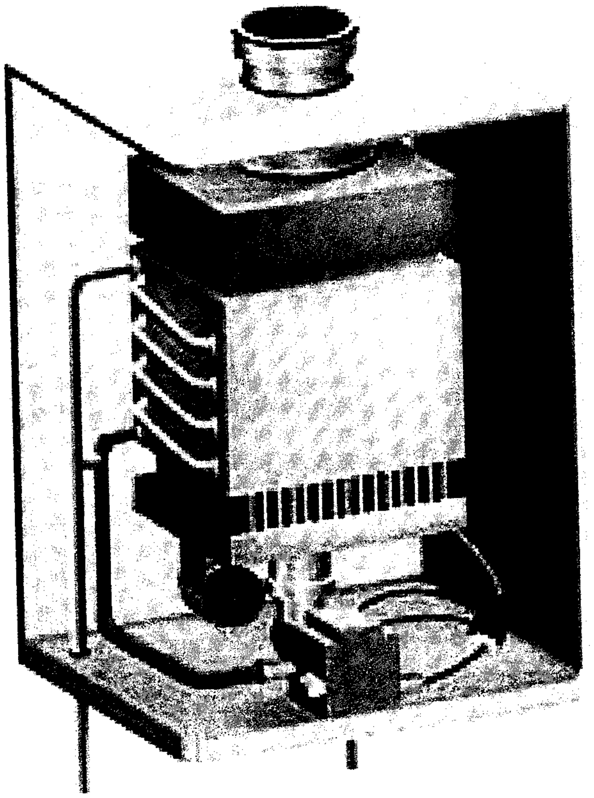
Standard Water Heaters

Tankless:

Gas or electric.

Can require special hookup service.

Effectiveness related to usage patterns.



Source: Energy Star

Standard Water Heaters

- Rated in gallons of tank size
- Home 40 – 80 gal.
- Commercial 100 gal. and above
- Tankless rated in BTU, typically <200K Btu for residential

Standard Water Heaters

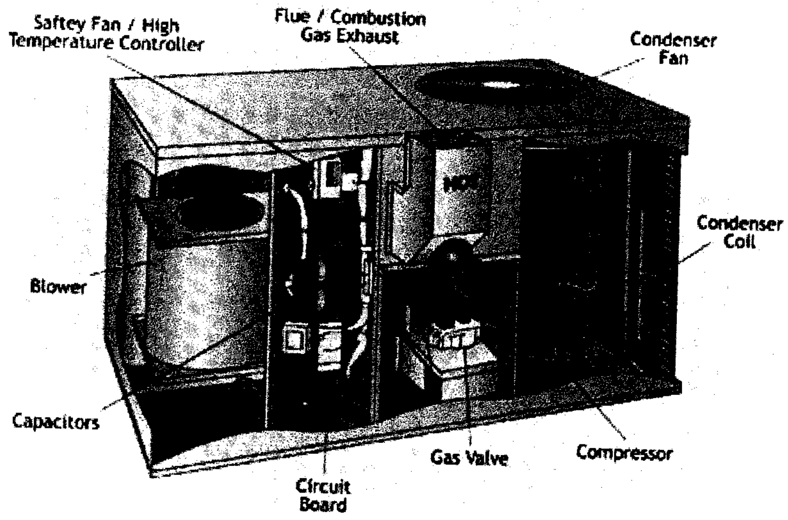
Efficiency

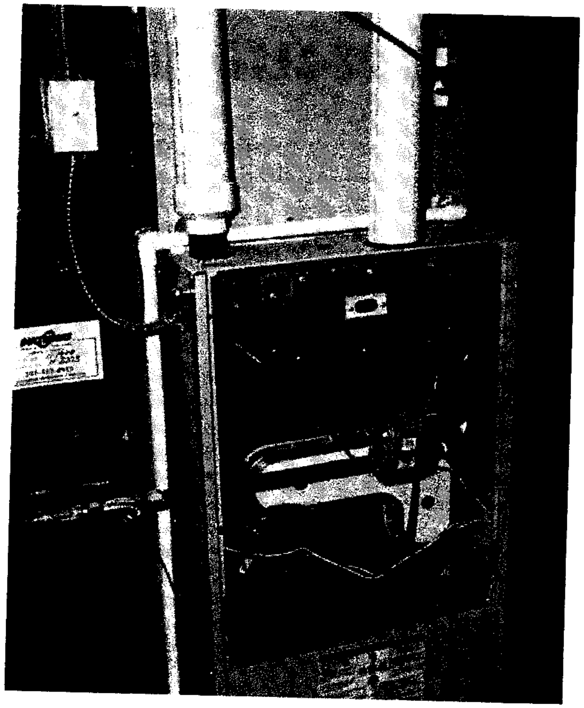
- AFUE rating
- Annual Fuel Utilization Efficiency
- Percent of total heat generated that enters ducts, or water
- Higher AFUE = more efficiency
- Old systems typically around 60 - 65, newer ones up to 95
- Current minimum 78 (most sold are 80)

Space Heating

Furnaces

- Rated in BTU (heat generating capacity)
- Small 50K
- Typical home 80 – 100K
- Commercial 100K and above





Courtesy of DOE/NREL

Heating

Efficiency

- AFUE rating
- Annual Fuel Utilization Efficiency
- Percent of total heat generated that enters ducts, or water
- Higher AFUE = more efficiency
- Old systems typically around 60 - 65, newer ones up to 95
- Current minimum 78 (most sold are 80)

The Thousand Home Challenge

www.thousandhomechallenge.org

To lay the foundation for transforming North American homes

Demonstrate the potential for 70-90% energy reductions in 1,000 existing homes.

SAGE BUILDING SOLUTIONS

Appendix D Heat Pump Duct Sealing Requirements

Duct Sealing is designed to improve the operation of existing heat pump systems that may be currently operating below their design efficiency. The program offers customer rebates to be applied to duct leakage testing and sealing conducted by a participating Santee Cooper contractor. Participating contractor must follow the acceptable procedures, requirements, documentation, and duct repair recommendations listed below.

Acceptable Procedures

- Duct pressurization test through a calibrated fan or orifice (duct registers are sealed, a fan is attached to one opening, the ducts are pressurized to match the system operating pressures, and the amount of air flowing through the fan is quantified; a commonly known system is Duct Blaster and there are several others a well).
- Blower door subtraction method (a calibrated fan measures whole-building leakage, then the duct grilles are sealed and the house re-measured; the difference is the amount of leakage attributable to the duct system)

Requirements

- Measure airflow across the indoor coil as per stated above in acceptable procedures and verify the CFM meets the requirements of ACCA Standard 5, and
- No more than 20% total CFM duct leakage (the total duct leakage requirement pertains to the percentage of CFM leakage as compared to the overall air handling fan flow operating at design conditions; the airflow leakage shall be based on the higher design airflow i.e. the higher of the winter heating airflow or of the summer cooling airflow), or 50% improvement on existing leakage or until 20% leakage requirement is met. Refer to specific equipment method for system pressurization requirements for testing.
- Existing systems with initial testing results of less than 20% leakage are not eligible for rebates.
- Only systems requiring repair are eligible for rebates.

Duct Repair Recommendations if CFM is not within the acceptable range

- Inspect the entire duct system
- Conduct minor repairs or replacement of damaged ducts
- Seal leaks and connections with mastic, metal tape, or an aerosol-based sealant
- Seal gaps behind registers and grills where the duct meets the floor, wall, or ceiling
- Insulate ducts in unconditioned areas with insulation that carries an R-6 value or higher
- Include a new filter as part of any duct system improvement
- Re-test the airflow after repairs are completed to insure requirements are met

Please see the "Santee Cooper Duct Sealing and Insulation Form, Commercial Prescriptive Rebate Program" for more specific details.

A WHOLE HOUSE APPROACH TO GREEN BUILDING & ENERGY EFFICIENT HOUSING

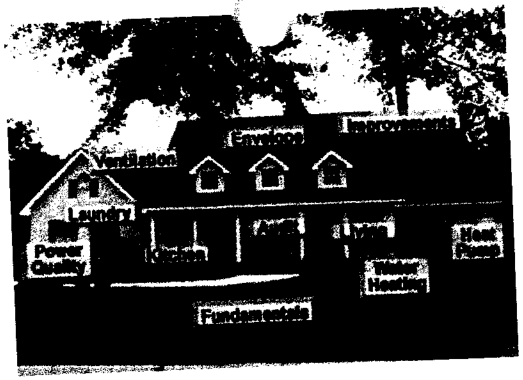
Let us show you how to reduce your utility consumption while reducing your carbon foot print.

Our trained professionals will guide you through our 3 step process:

1. *Home Energy Survey*
2. *Diagnostic Home Energy Audit*
3. *Comprehensive Home Energy Audit*

ENERGY STAR PARTNER

SHERLOCK HOMES
INSPECTION SERVICE INC
812-339-5828



Home Energy

Survey & Audits

Home Energy Survey is intended to assess the general energy performance of the home.

An Energy Survey identifies places in the home where energy is being wasted and prioritize the projects needed to fix them. This survey includes the use of an infrared camera. Infrared scanning, or thermography, is used to detect hot spots, cold spots and air leakage in building envelopes.
The end result of the Home Energy Survey is intended to reduce the amount of energy the home needs to operate and keep occupants comfortable.

A home energy Survey is just the first step in the process of lowering energy bills by making a home more efficient.

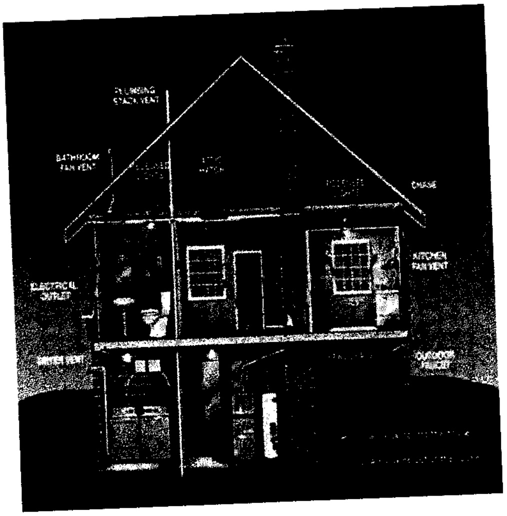
Diagnostic Home Energy Audits require the use of building performance-testing equipment (blower door, duct blaster, CO testers and the like) to measure, assess and document specific performance characteristics of the building system.

A blower door is a powerful fan that mounts into the frame of an exterior door. The fan pulls air out of the house, lowering the air pressure inside. The higher outside air pressure then flows in through all unsealed cracks and openings. These tests determine the home's rate of air infiltration.

Comprehensive Home Energy Audit includes all testing required in the Diagnostic Audit as well as an evaluation, performance testing and proposed treatments for improvement of an existing home. This Audit includes a computerized simulation analysis of the homes energy performance.

HOME ENERGY SURVEYS & AUDITS

NAHB GREEN VERIFICATION



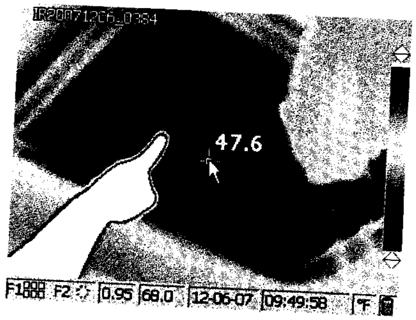
SHERLOCK HOMES INSPECTION SERVICE INC

812-339-5828

WWW.SHERLOCKHOMES.CC

√ HOME ENERGY SURVEY

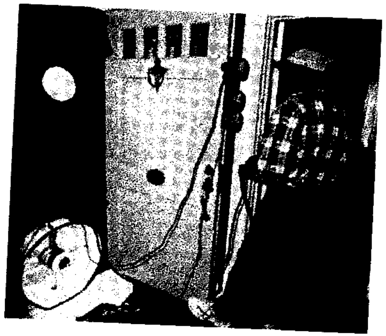
√THERMAL IMAGE CAMERA



√ ENERGY EVALUATION COMBUSTION SAFETY

√ DIAGNOSTIC TESTING DUCT LEAKAGE

√ DIAGNOSTIC TESTING AIR INFILTRATION BLOWER DOOR



√ COST EFFECTIVE ENERGY ANALYSIS

Energy Costs ($/yr)	As Is	With All Improvements	Savings
Heating	1214	714	499
Cooling	138	99	40
Hot Water	222	222	0
Lights and Appliances	389	403	-14
Service Charge	245	245	0
Total	2208	1683	525
HERS Index	141 ***+	100 ****	

FEE SCHEDULE

EXISTING HOUSING

HOME ENERGY SURVEY: INCLUDES THERMAL IMAGE CAMERA (WHEN ORDERED SEPERATLY)	$300.00
HOME ENERGY SURVEY: (WHEN ORDERED W/ ANY OTHER INSPECTION)	$200.00
DIAGNOSTIC AUDIT: (INCLUDES HOUSE LEAKAGE AND DUCT LEAKAGE TESTING)	$400.00
COMPREHENSIVE HOME ENERGY AUDIT (INCLUDES DIGNOSTIC AUDIT & COMPUTER SIMULATION OF PERFORMANCE)	$600.00

NEW CONSTRUCTION

PLAN REVIEW PROJECTED RATING (+.05¢ sq. ft. above 3000 sq. ft.)	$300.00
THERMAL BY PASS INSPECTION ONLY (REQUIRED WITH ENERGY STAR)	$125.00
DUCT LEAKAGE TESTING (WHEN ORDERED WITH THERMAL BY-PASS INSP.)	$125.00
CONFIRMED RATING DUCT BLASTER, HOUSE LEAKAGE TESTING (INCLUDES ENERGY STAR PROCESSING)	$350.00
NHAB GREEN VERIFACTION	$400.00

SHERLOCK HOMES INSPECTION SERVICE INC.
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EMAIL: sherlockhomesinspectors@comcast.net

Blower Door and Duct Blaster Testing

■ Diagnostics for an energy efficient house

Measuring house air leakage with a blower door

Air leakage can increase heating and cooling costs over 30% and contribute to comfort, health and safety problems. Finding hidden air leakage sites, called *bypasses,* can be difficult without the use of a blower door. This diagnostic equipment uses a fan to pressurize (force air into) or de-pressurize (force air out of) a building. When the fan operates, it is easy to feel the effects of *infiltration* - air leaking through cracks in the building envelope. Blower doors have gauges which can measure the relative leakiness of a building.

One measure of a home's leakage rate is air changes per hour (ACH), which estimates how many times in one hour the entire volume of air inside the building leaks to the outside. Leakier houses have higher ACH's, therefore higher heating and cooling costs, and greater potential for moisture, comfort, and health problems.

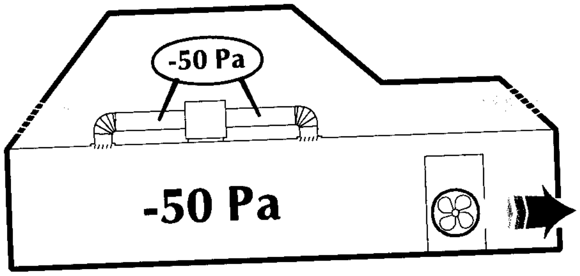
To determine ACH, the blower door creates a pressure difference of 50 Pascals between inside and outside. Fifty Pascals is approximately equivalent to a 20 m.p.h. wind blowing against all surfaces of a building. The leakier the house, the harder the fan must work to maintain the pressure. The amount of air the fan blows, measured in cubic feet per minute (CFM), is used to determine ACH.

Measuring duct leakage with a duct blaster

A duct blaster combines a small fan and a pressure gauge to pressurize a house's duct system and accurately measure air leakage of the ductwork. This test is similiar to a pressure test of a plumbing system. Duct leakage can increase heating and cooling costs over 30% and contribute to comfort, health and safety problems.

House set-up

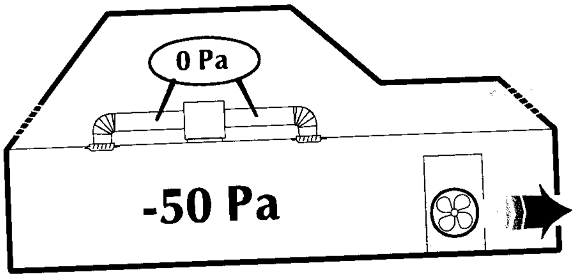
Consistent test methods are used throughout and include: Taping over the dryer vent hookup if no dryer is present, turning combustion appliances in conditioned space to "off" or "pilot", closing and locking all windows and doors, including storms, turning off all fans or mechanical blowers, opening interior doors, and closing all closet doors.



Blower door - ***untaped*** - *Depressurize house and ducts*

Blower door - *untaped*

The blower door measures the airflow (CFM$_{50}$) required to depressurize the house to -50 Pascals (~0.2 inches w.c.). This test condition is known as ***Untaped*** and is the basis for the Air Changes per Hour calculation, ACH$_{50}$ = CFM$_{50}$ x 60 / house volume.



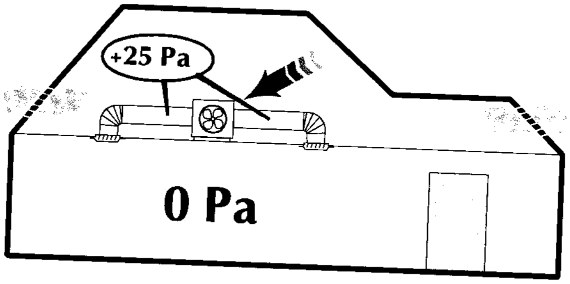
Blower door - ***taped*** - *Depressurize house only*

Blower door - *taped*

After taping over all the supply and return duct grilles, a second blower door test determines the ***Taped*** CFM$_{50}$ measurement. This number indicates how much air leakage is through the building envelope only, because any duct loss is blocked out.

Subtracting the *Taped* measurement test value from the *Untaped* value gives a rough estimate of the total duct leakage. This test is often unreliable at estimating duct leakage.

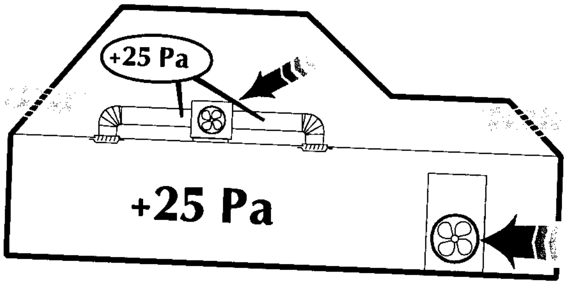
Prepared by the Southface Energy Institute • *241 Pine St., Atlanta, GA 30308* • *404/872-3549* • *fax 404/872-5009* • *info@southface.org* • *http://www.southface.org*
For Georgia Environmental Facilities Authority • *2080 Equitable Bldg., 100 Peachtree St., NW* • *Atlanta, GA 30303* • *404/656-5176*
RECYCLED PAPER 1/16/97



Duct blaster-*total*- *Pressurize ducts only*

Duct blaster- *total*

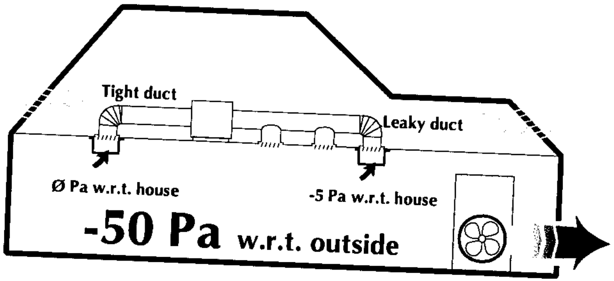
The duct blaster is connected to the air handler to pressurize the taped-over duct system to 25 Pascals. This is about the pressure that an HVAC system normally experiences. The blower door is not used for this test. The ***Total*** CFM$_{25}$ amount of duct leakage is determined.



Duct blaster & blower door - *to outside* -
Pressurize ducts and house

Duct blaster- *to outside*

Since some duct leakage usually occurs within the conditioned space and is not necessarily bad from an energy standpoint, an additional duct test is performed to measure leakage ***To Outside***. For this test, the blower door is used to pressurize the house to 25 Pascals and the duct blaster pressurizes the ductwork to the same level. All duct leakage measured is to the outside, or unconditioned space, and represents heating or cooling energy lost.



Blower door - *pressure pan*- *Depressurize house*

Blower door - *pressure pan*

The blower door can be a useful diagnostic tool in determining the relative amount of leakage in a particular duct run. For the ***Pressure Pan*** test, the duct system and blower door are set-up as in the *Untaped* test - no masking tape on any registers, house depressurized to -50 Pascals w.r.t. (with respect to) the outside. A highly accurate pressure guage connected with a tube to a covering pan is placed over a single register and the pressure inside of that register is measured. If the particular duct run is fairly tight, the pressure inside the register will read close to the house pressure (say, -49 Pascals w.r.t. the outside, or -1 Pascal w.r.t. the house). If the duct run is excessively leaky or partially disconnected, the pressure inside the register will vary considerably from the rest of the house (say, -45 Pascals w.r.t. the house, or -5 Pascals w.r.t. the house). A quick test of all registers will tell which have the leakiest duct runs.

Blower door — *test results - building tightness*

Newly constructed homes in the 1,500 - 2,500 ft^2 range should test at less than 8 ACH at 50 Pascals pressure (8 ACH$_{50}$). Reasonable air-sealing efforts that are required by the Georgia Energy Code, usually will yield a range of 5 to 7 ACH$_{50}$ or better. Older houses tend to be between 10 and 20+ ACH$_{50}$ but there is broad variation. Energy efficient homes with controlled ventilation often have tightness levels of 1 to 5 ACH$_{50}$.

Duct blaster — *test results - ductwork and mechanical*

Ductwork for mechanical systems should be sealed tightly with mastic and at least pass a level of duct tightness of 5-7% of the floor area; e.g., a 1,000 square foot house could have up to 50-70 cfm of leakage in the ductwork. These levels are easily achievable with a moderate sealing effort. The Georgia Energy Code requires all joints and seams in ductwork to be sealed with mastic and to be insulated to R-5 or better when located in unconditioned spaces, such as attics or crawlspaces. Duct tape is not allowed as a sealant.

Blower Door and Duct Blaster Testing for Duct & Envelope Tightness Verification

Southface
241 Pine St. NE, Atlanta, GA 30308
www.southface.org

Prepared by Southface Energy Institute – March, 2011

Fact Sheet

Diagnostics for an energy efficient house

Measuring house air leakage with a blower door

Air leakage can increase heating and cooling costs over 30% and contribute to comfort, health and safety problems. Finding hidden air leakage sites, called *bypasses*, can be difficult without the use of a blower door. This diagnostic equipment uses a fan to pressurize (force air into) or depressurize (force air out of) a building. When the fan operates, it is easy to feel the effects of *infiltration* – air leaking through cracks in the building envelope. Blower doors have gauges which can measure the relative leakiness of a building.

One measure of a home's leakage rate is air changes per hour (ACH), which estimates how many times in one hour the entire volume of air inside the building leaks to the outside. Leakier houses have higher ACH's, therefore higher heating and cooling costs, and greater potential for moisture, comfort, and health problems.

To determine ACH_{50}, the blower door creates a pressure difference of 50 Pascals between inside and outside. Fifty Pascals is approximately equivalent to a 20 m.p.h. wind blowing against all surfaces of a building. The leakier the house, the harder the fan must work to maintain the pressure. The amount of air the fan blows, measured in cubic feet per minute (CFM), is used to determine ACH.

Measuring duct leakage with a duct blaster

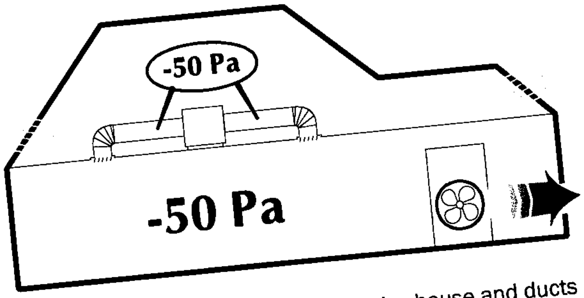
A duct blaster combines a small fan and a pressure gauge to pressurize a house's duct system and accurately measure air leakage of the ductwork. This test is similiar to a pressure test of a plumbing system. Duct leakage can increase heating and cooling costs over 30% and contribute to comfort, health and safety problems.

House set-up

Consistent test methods are used throughout and include: Not taping over the dryer vent hookup if no dryer is present, turning combustion appliances in conditioned space to "off" or "pilot", closing and locking all windows and exterior doors, including storms, turning off all fans or mechanical blowers and opening interior doors.

Blower door - untaped

The blower door measures the airflow (CFM_{50}) required to de-pressurize the house to -50 Pascals (~0.2 inches w.c.). This test condition is known as ***Untaped*** and is the basis for the Air Changes per Hour calculation, $ACH_{50} = CFM_{50} \times 60$ / conditioned house volume.

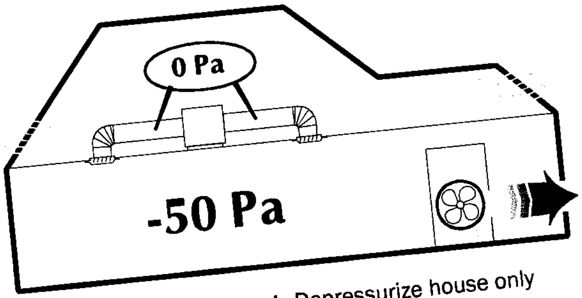


Blower door - ***untaped*** - Depressurize house and ducts

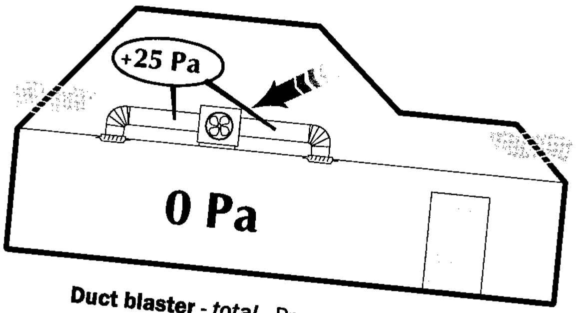
Blower door - taped

After taping over all the supply and return duct grills, a second blower door test can be performed to determine the ***Taped*** CFM_{50} measurement. This number indicates how much air leakage is through the building envelope only, because any duct loss is blocked out.

Subtracting the ***Taped*** measurement test value from the ***Untaped*** value and adjusting the figure with the subtraction correction factor (SCF) gives a rough estimate of the total du leakage. Several tests use this technique–the ***modified blowe door subtraction*** (MBDS) and the more accurate ***automated multi-point blower door*** (AMBD) methods. While these tests are approved for duct tightness verification, the duct blaster is the preferred tool, as it provides a more direct measurement of leakage with a smaller margin of error.

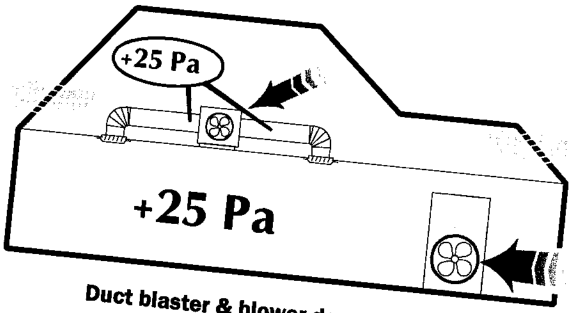


Blower door - ***taped*** - Depressurize house only



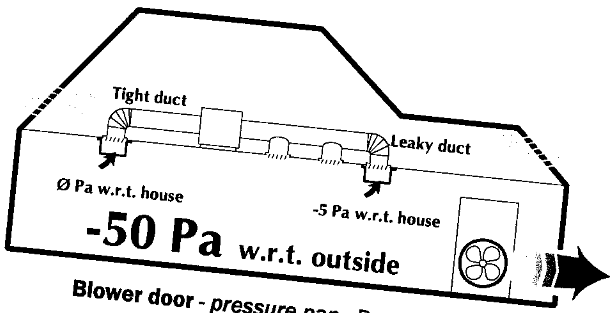
Duct blaster - *total* - Pressurize ducts only

Duct blaster - *total leakage*
The duct blaster is connected to the air handler to pressurize (or depressurize) the taped-over duct system to 25 Pascals. This is about the pressure that an HVAC system normally experiences. The blower door is not used for this test. The ***Total*** CFM_{25} amount of duct leakage is determined.



Duct blaster & blower door - *to outside* - Pressurize ducts and house

Duct blaster - *leakage to outside*
Since some duct leakage may occur within the conditioned space and is not necessarily bad from an energy standpoint, an additional duct test is performed to measure ***Leakage To Outside***. For this test, the blower door is used to pressurize the house to 25 Pascals and the duct blaster pressurizes the ductwork to the same level. All duct leakage that is measured is lost to the outside, or unconditioned space, and represents heating or cooling energy that is directly wasted.



Blower door - *pressure pan* - Depressurize house

Blower door - *pressure pan*
The blower door can be a useful diagnostic tool in determining the relative amount of leakage in a particular duct run. For the ***Pressure Pan*** test, the duct system and blower door are set-up as in the ***Untaped*** test - no masking tape on any registers, house de-pressurized to -50 Pascals w.r.t. (with reference to) the outside. A highly accurate pressure gauge connected with a tube to a covering pan is placed over a single register and the pressure inside of that register is measured. If the particular duct run is fairly tight, the pressure inside the register will read close to the house pressure (say, -49 Pascals w.r.t. the outside, or -1 Pascal w.r.t. the house). If the duct run is excessively leaky or partially disconnected, the pressure inside the register will vary considerably from the rest of the house (say, -45 Pascals w.r.t. the outside, or -5 Pascals w.r.t. the house). A quick test of all registers will tell which have the leakiest duct runs. This method cannot be used to determine or quantify the duct leakage of a system.

Blower door — *test results - building tightness*
Newly constructed homes should test at less than 7 ACH at 50 Pascals pressure (7 ACH_{50}). Reasonable air-sealing efforts that are required by the Georgia Energy Code, usually will yield a range of 5 to 7 ACH_{50} or better. Older houses tend to be between 10 and 20+ ACH_{50} but there is broad variation. Energy efficient homes with controlled ventilation often have tightness levels of 1 to 5 ACH_{50}.

Duct blaster — *test results - ductwork and mechanical*
Ductwork for mechanical systems should be sealed tightly with mastic and at least pass a leakage to outside level of duct tightness of 8% of the floor area; e.g., a 1,000 square foot house could have up to 80 cfm of leakage in the ductwork. These levels are easily achievable with a moderate sealing effort. The Georgia Energy Code requires all joints and seams in ductwork to be sealed with mastic and to be insulated to R-6 or better when located in unconditioned spaces, such as a crawlspace, and R-8 when located in an attic. Duct tape is not allowed as a sealant.

BPI ENVELOPE 5-DAY TRAINING AGENDA

Using a "whole house" performance-based approach, this training will cover **advanced building** envelope diagnostic, evaluation, recommendations and repair skills to help you prepare for the Building Performance Institute's **Envelope Professional** written and field exams. Training will include review of some **Building Analyst** topics.

Prerequisites:

- Building training or BPI Building Analyst Certification

Day 1 8:00 – 4:30 – Classroom

- Introduction
- Overview of training - building observation skills and advance diagnostics
- Discussion of BA Review through this training
- AM
    - a. House as a System
    - b. Health and Safety
    - c. Heat Transfer
    - d. Moisture
    - e. Psychometrics
    - f. Thermal Boundary
    - g. Pressure Boundary
- PM
    - a. Thermal Boundary Basics
    - b. Insulation Basics
    - c. Rating Effectiveness of Installation
    - d. Composite R-Value of Wall Assembly
    - e. Installation Standards and Practices
    - f. Estimating Cellulose Quantity
    - g. Advanced Installation Techniques
    - h. Evaluating Windows and Doors

Day 2 8:00 - 4:30 – Classroom

- Communicating with your Client
- Mechanical Ventilation
- Pressure Diagnostics I
- Pressure Diagnostics II
- Duct Blaster
- Distribution / AFUE seasonal load percentages
- Diagnosing and Treating the Forced Air Distribution System
- Combustion Safety

Day 3 8:00 – 4:30 Full-day Field Class

- Data intake
- Building assessment calculations
- Comprehensive assessments
- Building airflow standards (BAS)
- Psychometrics
- Gas leak detection
- Combustion Appliance Zones (CAZ) and combustion safety
  - CAZ Depressurization rates
  - Draft for the day
  - In-depth CAZ testing
  - Worst Case Scenario
  - Spill / Draft / CO
  - Equipment operation
  - CFM for combustions appliances
- Pressure differentials using charts and equipment
- CFM test for Spot ventilation
- Heating systems and DHW
- Blower Door
- Duct Blaster
- Pressure differentials
- Charting CFM reductions to ID Pressure differential problems
- Scope of Work

Day 4 8:00 – 4:30 Full-day Field Class – Mirror Day 3 but get Students to set up home and equipment

- Data intake
- Building assessment calculations
- Comprehensive assessments
- Building airflow standards (BAS)
- Psychometrics
- Gas leak detection
- Combustion Appliance Zones (CAZ) and combustion safety
  - CAZ Depressurization rates
  - Draft for the day
  - In-depth CAZ testing
  - Worst Case Scenario
  - Spill / Draft / CO
  - Equipment operation
  - CFM for combustions appliances
- Pressure differentials using charts and equipment
- CFM test for Spot ventilation
- Heating systems and DHW
- Blower Door
- Duct Blaster
- Pressure differentials
- Charting CFM reductions to ID Pressure differential problems
- Scope of Work

Day 5 7:30 – **11:30** Classroom (important to stop and allow students to study or ask questions for either written exam – BA or Envelope)

- Review the homes from the field
- Discuss Cost effectiveness Measures
- CAZ review
- Review

1:00 – 2:00 – Review and get laptops up and ready & be signed on to BPI testing site.

2:00 – 4:00 ***Students need to bring a laptop for online testing***

- Building Analyst 1 Written Exam 100 questions for first time students followed by a envelope written exam
- Envelope 50 question exam for those that passed the BA written exam earlier in past trainings

Student Equipment List

1. Notebook
2. Pen/pencil
3. Calculator
4. Clipboard
5. Graph paper (recommended)
6. Manometer (recommended) if they have one
7. Laptop (Day 5 only)

The Resource
Your Most Trusted Energy Resource
CONSUMERS ENERGY
Your Energy Cooperative
Volume 7 · Issue 2 | A Publication of Consumers Energy | March 2010

Home Energy Check-Up

Energy Audit Options

- **Thermal Imaging — Insulation Check** [Fee $150]
  Checks for thermal problems related to insulation of a home, heat loss/gain around windows and doorways and can help identify moisture problems in structure of a home. Provides color photos of problem areas. Recommend combining with Blower Door Test.

- **Blower Door Test — Air Infiltration of Home** [Fee $200]
  Checks for areas where air leaks into or out of the home. Identifies locations to tighten up the home with caulk or weather strip. Evaluates exterior doors and windows for leaks. This test is good to combine with Thermal Imaging and/or Duct Blaster Test.

- **Duct Blaster — Furnace Ductwork Integrity Test** [Fee $200]
  Checks for leaks in furnace ductwork which results in lost energy. Evaluates ductwork in "unconditioned" space, such as crawlspaces and attics, where any leaks are considered 100% lost energy. This test is great for new homes still under construction where ducts are accessible. This test is good to combine with Blower Door Test.

- **HERS® — Home Energy Rating System** [Fee $500]
  Certified rater provides a review of technical specifications of a home. This test is used to qualify for Energy Tax Credit (ETC)-Builders only. It is also used to qualify for utility rebates/incentives for non-conventional home construction such as icynene/foam insulation, vaulted ceilings, etc.

- **Energy Star® Rating–E★Star** [Fee $550]
  This test is a nationally recognized energy efficiency certification and used to qualify for utility rebates or incentives. It is also used to qualify for EE & EI mortgages and the Energy Star® certificate can be an asset in selling a home. New home must be inspected prior to drywall for thermal bypass checklist. Blower Door and Duct Blaster Test after completion of construction.

What's Your Home's Energy Rx?

Home Energy Check-Ups performed in 2009 identified up to $600 per home in energy leaks due to air infiltration.

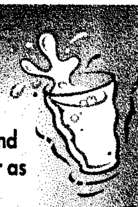
✓ Do you think you have a "drafty home"?

✓ Do you want to know what would be prescribed to reduce those energy leaks and reduce your energy costs?

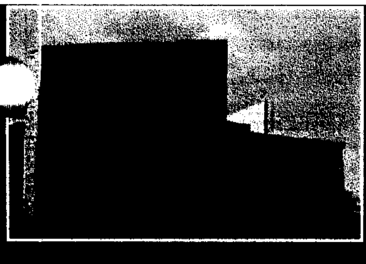
✓ Call Consumers Energy and talk to C.D. Kendall about having a Home Energy Check-Up by having thermal imaging and a blower door test performed on your home.

✓ Your payback could be less than a year!

Energy Fun Facts



- An energy-smart clothes washer can save more water in one year than one person drinks in an entire lifetime!
- A crack as small as 1/16th of an inch around a window frame can let in as much cold air as leaving the window open three inches!
- Every time you open the refrigerator door, up to 30% of the cold air can escape.
- Every year more than $133 billion worth of energy leaks from houses through small holes and cracks. That's more than $150 per family!



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www.consumersenergy.coop

Office Hours
7:30 am — 4:30 pm
Monday through Friday

Consumers Energy's New Residential Energy Efficiency Incentive Programs

Effective January 1, 2010

Program/Measure		2010 INCENTIVES (per unit unless specified)
WATER HEATING		
Heat Pump Water Heaters		
	Add-on unit (separate tank)	$300
	Integrated Unit	$500
Solar Water Heaters (w/ Electric auxiliary tank)		$350
High Efficiency Electric Water Heaters		
	40-49 gallon, EF 0.94	$50
	50-79 gallon, EF 0.94	$100
	80 gallon+ , EF 0.92	$150
Drainwater Heat Recovery Pipes		$300
APPLIANCES / ELECTRONICS		
ENERGY STAR Refrigerator		$25
ENERGY STAR Freezer		$25
ENERGY STAR Dishwasher (w/ electric water heater)		$25
ENERGY STAR Clothes Washer		
	w/ Electric Water Heater	$35
	w/ Electric Dryer	$35
	BOTH Electric Water Heater & Dryer	$70
ENERGY STAR Dehumidifier		$25
High Efficiency TV (CEE Tier 4, Screen ≥40")		$40
ENERGY STAR Compact Fluorescent Lamps (self-ballast/screw-in, 9W min.)		$2 / lamp
ENERGY STAR CFL Fixtures (Hard-wired)		$8 / fixture
ENERGY STAR Ceiling Fan (w/ attached pin-type CFL lighting)		$15 / fixture
Energy Star LED/SSL lighting (10 watt min.)		$30 / lamp or fixture
T8 and T5 Lighting Fixtures (ballast(s) and lamp(s), New or Replacement)		
	2 Foot Fixtures	$4/ lamp
	4 Foot Fixtures (46" for T5)	$5/ lamp
	8 Foot Fixtures	$7/ lamp
EXTERIOR LIGHTING/SECURITY LIGHTING		
High Pressure Sodium (ballast and lamp, Replacement Only)		
	50-99 Watt Fixture(Replacement Only)	$15 / fixture
	≥100 Watt (Replacement Only)	$30 / fixture
Pulse Start Metal Halide Fixtures (ballast and lamp, no probe start)		
	70W to 249W (Replacement Only)	$20 / fixture
	≥ 250 Watts (Replacement Only)	$30 / fixture
Outdoor CFL (cold start ballast rated to -20°)		$15 / fixture
HEATING AND COOLING		
Heat Plus Rate		$100 per home
Geothermal Heat Pumps	Closed Loop	$350 / ton
	Open Loop	$250 / ton
	Unit Replacement (existing loop)	$150 / ton
Air Source Heat Pumps	Standard ASHP	$150 / ton
	ENERGY STAR Bonus (add to standard ASHP rebate)	$250 / unit
Heat Pump Compressor Replacement		$100
Residential Contractor Rebate		$200 / home
ENERGY STAR Central AC		
	SEER 14.5 (and EER 12)	$100
	SEER 16 (and EER 13)	$150
ENERGY STAR Room Air Conditioner		$25
Indoor Air Quality Devices (Whole house - Electronic Air Filter, UV, Radon)		$50
Heat Recovery Ventilators		$125
NEW HOME CONSTRUCTION		
All-Star Home (new construction, Elect. Heat & Water Heating)		$500 / home
Advanced Lighting Package (add to All-Star)		$200 / home

SI | 10

The Sustainability Institute

HISTORIC CHARLESTON FOUNDATION

Energy Efficiency in Historic Residences: A Case Study

Benjamin Leigh and Sarah Welniak

With contributions by Winslow Hastie and April Wood

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www.sustainabilityinstitutesc.org
May 2010

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Introduction

Historic preservation and green building share the fundamental goal of preserving natural resources and promoting sustainable, vibrant communities. Traditionally, preservation has been discussed in terms of its cultural value to society, but increasingly preservation is being promoted for its environmental values as well. Existing buildings, historic or otherwise, have an inherent embodied energy value. The energy and natural resources consumed during the construction process of existing buildings has already been expended and realized, and this significant investment of resources should be valued. Demolition and new construction waste additional natural resources and expend tremendous amounts of additional energy. From a resource management perspective, renovating and rehabilitating historic structures exemplifies green building at its core—adaptive reuse and the efficient use of energy.

Despite this fact, historic buildings have gained a stigma for being unsustainable, primarily due to higher operational costs. Newer, "green" buildings are often hailed as clean and efficient based solely on lower energy operational costs. In many cases the green building movement is product-driven, encouraging consumers to replace products in their homes, or build new buildings, in an effort to become more energy efficient. This process is often expensive and invasive, without a commensurate increase in efficiency. Energy efficiency retrofits should always be performance-based to ensure that the renovations are targeted and strategic. Renovating with a focus on preservation principles provides owners of historic homes the ability to reap the benefits of the embodied value of their historic building while at the same time lowering its operational costs. Historic structures are inherently sustainable and will continue to be if their sound construction and superior materials are preserved properly. This important fact is supported by the research in this case study.

This study is the result of a partnership between the Sustainability Institute and Historic Charleston Foundation. The partnership focuses on bringing broader public awareness to the inherent efficiency in historic buildings and outlines the most cost-effective ways to make an historic building more energy efficient. To substantiate these assertions, we analyzed five historic structures in Charleston, South Carolina to assess their energy efficiency capabilities in the context of a warm, humid climate. Through modeling, performance testing, and careful analysis of the buildings within their climate context, this study proves that historic structures are capable of much higher levels of efficiency than generally thought. Using the *Secretary of Interior's Standards for Rehabilitation* as a guideline, this study seeks to prove that increased energy efficiency and reduced environmental impact are possible while maintaining and preserving the historic fabric of existing buildings. Through this analysis, this case study emphasizes the vital role historic preservation plays in sustainability both in the Lowcountry of South Carolina and around the world.

How are historic buildings energy efficient?

Historic buildings are often located in dense, mixed-use communities where walking and biking to neighborhood resources provide a reasonable alternative to driving. From a sustainability perspective, avoiding long drives to neighborhood amenities makes living in historic communities a more efficient use of natural resources. Adaptive reuse of historic buildings preserves the neighborhood fabric and drastically reduces the environmental impact of our daily activities.

Aside from location, one of the principal highlights of historic buildings that contribute to their sustainability profile is their embodied energy. *Embodied energy* is the sum total of energy necessary for an entire product lifecycle. This lifecycle includes raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and/or decomposition. In a recent article from *Preservation* magazine, Wayne Curtis rationalizes adaptive reuse and renovation rather than "building from scratch". He writes:

> "When people talk about energy use and buildings, they invariably mean operating energy: how much energy a building—whether new or old—will use from today forward for heating, cooling, and illumination. Starting at this point of analysis—the present—new will often trump old. But the analysis takes into account neither the energy that's *already bound up* in preexisting buildings nor the energy used to construct a new green building instead of reusing an old one."[1]

Curtis goes on to quote Mike Jackson, chief architect with the Illinois Historic Preservation Agency: "Old buildings are a fossil fuel repository, places where we've saved energy." By accounting for the energy stored in our historic buildings, we can take advantage of the "non-recoverable energy embodied in an existing building and extending the use of it." Therefore, adaptive reuse is generally the most efficient use of resources

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[1] Wayne Curtis. *"A Cautionary Tale: amid our green building boom, why neglecting the old in favor of the new might cost us dearly"*, (New York, *Preservation* magazine, 2008)

because it takes advantage of the significant embodied energy encapsulated in an existing building. [2]

By design, most historic homes were originally energy efficient. Historic homes were often built before the advent of air conditioning and they utilized the earth's natural energies, such as sunlight and wind, to provide for heating and cooling. In Charleston, these passive features were designed to catch coastal breezes, bring in natural light, provide shade, and capture rainwater for household use. Several of the buildings in this study are Charleston single houses, a vernacular building typology in the city. The Charleston single house utilizes many features that were created to adapt to the climate. These buildings were typically two or three stories over an open basement or crawl space, which provided height to catch the ocean breezes, even if they were not immediately next to the water.[3] The piazzas, or covered porches, were usually located along the south or west elevations, which shaded the building from intense sun and helped to funnel the prevailing breezes to all levels of the building.[4] These passive features are another sustainable aspect of historic properties.

Today, many sustainably focused companies utilize these same design techniques to achieve increased efficiency in new buildings, but with a noticeably more contemporary building shell. Examples of using historic building techniques in modern construction include daylighting strategies that offer natural lighting without heat gain,

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[2] Ibid.

[3] Gerald F. Foster. *"American Buildings: A Field guide to the Architecture of the Home"*, (New York: Houghton Mifflin Harcourt, 2004): 154.

[4] Ibid.

siting the building footprint to take advantage of passive solar energy, and using rainwater collection systems to capture water for landscape irrigation or toilet wastewater. These centuries-old techniques can effectively be applied to new construction to increase efficiency beyond high efficiency heating and cooling systems. In historic buildings, rediscovering these passive systems can constitute a strong foundation from which to build increased efficiency.

The addition of heating and cooling (HVAC) mechanical systems to historic buildings can create the largest obstacle to realizing efficiency gains. Ill-designed and poorly installed HVAC systems not only increase the energy consumption of a building but can also cause irreparable harm to the building. Originally, historic buildings were designed to take advantage of natural breezes in the Lowcountry. Additionally, these buildings rarely included insulation, making heat gain a constant issue when employing modern heating and cooling strategies. The standard approach to addressing infiltration and heat gain during rehabilitation has been to drastically increase the capacity of the HVAC system to overcome the indoor conditions of the homes. This process requires an extraordinary amount of energy and can be a catalyst for numerous problems that may impact the historic integrity of the structure. Sensitive retrofitting that protects the material integrity of the structure and increases the energy efficiency of the building is certainly possible. The impact and methodology of these retrofits are the focus of this report.

National and international efforts towards energy efficiency

The National Trust for Historic Preservation (the Trust) is a national, non-profit organization that seeks to "save historic places and revitalize America's communities."[5] Perhaps the most notable of their recent initiatives is their involvement in the ever-expanding "green" movement, partly exhibited by the dedication of the January/February 2008, March/April 2009, and March/April 2010 editions of *Preservation* magazine to "Green Issues." These issues are a part of their growing sustainability initiative, which focuses on promoting public policy (at the local, state, and federal levels) that supports the nexus of sustainability and preservation, facilitating new research in this rapidly expanding field, and providing outreach to local governments, practitioners, and property owners. The Trust has also established a Green Lab in Seattle, Washington in an effort to educate the public on retrofitting historic structures for increased efficiency. The primary goals of the Green Lab are to "develop and implement policies that support green retrofits and adaptive reuse, as well as reinvestment in existing communities." They intend to achieve this by setting up retrofitting projects both in Seattle and across the country in order to lead by example on this important issue. The current pilot cities are Seattle, Washington, San Francisco, California, and Dubuque, Iowa. The Trust's Green Lab is just the first of many research facilities that will continue to expand on the understudied subject of the energy performance of historic buildings.

The notion of promoting the inherent sustainability of historic buildings is not a new concept. During the late 1970s oil crisis, the preservation community was stalwartly

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[5] The National Trust for Historic Preservation, "About Us" www.preservationnation.org/about-us.

focused on the issue of energy efficiency and historic buildings. The National Trust produced a popular poster with an historic building in the shape of an oil can which read: "It takes energy to construct a new building. It saves energy to preserve an old one." The Trust has promoted the sustainability of historic buildings through the years, but the recent renewed international focus on sustainability has re-energized the preservation community's focus on energy efficiency in historic buildings.

Many U.S. cities are beginning to understand the impact that the residential sector has on the overall U.S. consumption of energy. As a result, cities like San Francisco, Berkeley, and Austin have created ordinances that require certified energy audits when properties are sold. These cities are implementing these policies in an effort to offset peak energy load and prevent the necessity of new power generation facilities. Many have embraced the idea of conservation as the quickest and most efficient method for securing energy independence.

Internationally, the European Union (EU) has increased its focus on energy efficiency across the continent. Many countries within the EU are requiring energy performance certificates to be produced whenever a building is constructed, sold or rented in order to keep an up-to-date measure of the efficiency of the structure.[6] Irish law, for example, requires all buildings for sale or lease, to have an energy efficiency certificate. Understanding the impact of such regulations on historic buildings, The English Heritage, a government-funded historic preservation group, has also produced a

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[6] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings: http://europa.eu/scadplus/leg/en/lvb/l27042.htm.

guide to help building owners increase energy efficiency in historic structures without compromising the integrity of the building. This guide is tailored specifically to climate conditions and building materials found in historic structures in England so that retrofitting helps to improve energy efficiency, while protecting historic integrity of the buildings.

Similarly, this case study seeks to analyze energy consumption in historic structures in Charleston and to begin the development of guidelines that can increase the efficiency of such properties. The Trust's efforts are timely with respect to the efforts of the Charleston Green Committee (the "CGC") to create the Plan for Climate Protection and Sustainability for the City of Charleston.[7]. Comprised of 24 business, academic, nonprofit and government leaders, the CGC recognizes that buildings are the primary contributor to Charleston's greenhouse gas emissions for which it is working to establish and implement energy efficiency standards including retrofitting guidelines within a historic context. With over 3,000 historic structures on the peninsula and a sophisticated base of knowledge in historic preservation and restoration, Charleston serves as an ideal laboratory for developing energy efficient retrofitting techniques that also preserve the historic integrity of our building stock. In furthering its mission, the Trust may have an unprecedented opportunity to selectively collaborate with CGC to protect and enhance the historic and environmental qualities distinct to Charleston.

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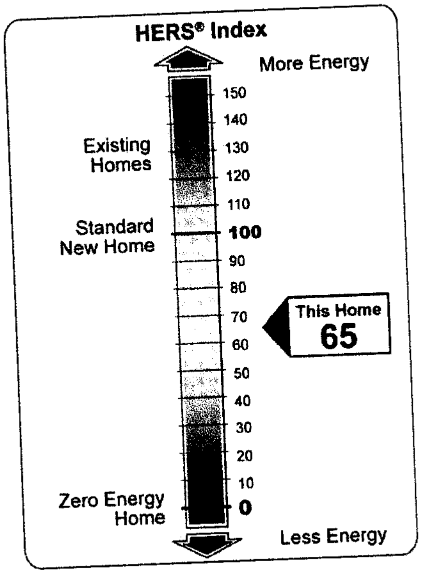
[7] Charleston Green Committee, http://www.charlestongreencommittee.com/index.html

RESNET and HERS

National efficiency efforts began to take root in the United States in the early 1990's. In 1995 a collaborative of state energy officials and mortgage lenders formed the Residential Energy Services Network (RESNET). RESNET's goal was to make energy efficient homes available to more people. To achieve this goal, RESNET developed a national standard for rating a home's energy efficiency, the Home Energy Rating System Index (HERS Index). The index is a relative energy use scale similar to a miles-per-gallon rating on a car, but measures a home's energy use instead of fuel. A rating of zero indicates that the home uses no net-purchased energy. The standard 'new American' home built to the adopted International Energy Conservation Codes (IECC) is assumed to have a HERS rating of 100. An Energy Star Home, which is a green built home designed to use notably less energy and water, achieves an index of 85, which is 15% more efficient than a home built to code. A lower HERS rating means the house is performing more efficiently.



Research Goals

The goal of this research is to establish guidelines for improving the energy efficiency of Charleston's historic residential buildings without negatively impacting their historic integrity. Baseline energy models using the Home Energy Rating System developed by RESNET were used to establish improvement analyses for each of the buildings in the study. Improvement analyses identified the most cost-effective, practical, and historically sensitive retrofits that will improve energy use. This case study offers specific recommendations to improve the energy efficiency of each building within the study; however, it also analyzes broader trends to identify strategic improvements that apply to all historic buildings in Charleston.

Methodology

The historic structures in this study were analyzed using the Home Energy Rating System (HERS) protocol and The Sustainability Institute's analysis and reporting procedure. This procedure consists of four stages: site visit, baseline energy modeling, improvement analysis, and reporting.

Site Visit

The site visit includes measurement of the building envelope components, gathering information on the efficiencies of mechanical equipment, blower door testing, and duct blaster testing. During the site visit, researchers measure the exterior of the building, often called the building "envelope". The total square footage, volume, and glazing area of the building are calculated.[8] The frequency of glass openings and their degree of shading throughout the day impacts the energy efficiency of the building as a result of passive heating or cooling. For this reason, the site visit also includes the notation of operable shutters, trees, and even nearby buildings to determine the natural air changes per hour in the analysis of the testing data. Other notes taken while on site

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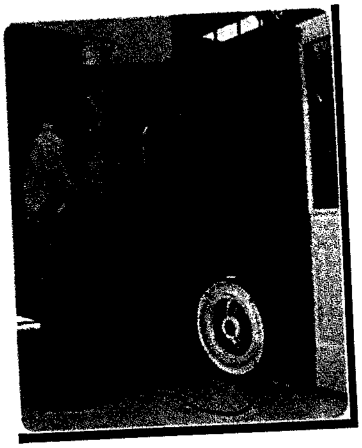
[8] The glazing area is the amount of glass, whether in windows or doors, that is present on the exterior walls of the building.

visits include the method of construction, the conditions and types of attic and crawl spaces, and the specific sizes and types of mechanical systems currently in place.

Blower Door Testing

All site visits included blower door testing using a Minneapolis Blower door assembly. A blower door is a calibrated fan assembly that measures the amount of leakage through the exterior floors walls and ceilings of a building. The fan depressurizes the house by pulling the interior air out of the house. Every cubic-foot-per-minute (CFM) of air leaving the building must be replaced by an equal amount of outside air. Based on this principle, the blower door assembly can estimate the amount of air leakage through the building shell.



This assembly can also be used to locate the source of leakage. As the fan activates, the change in pressure exacerbates the leakage coming through gaps and cracks in the building's shell. Simply holding a hand in front of a likely leakage location can indicate the source of the leakage. In many instances, homeowners participate along with researchers by locating and marking leakage points for later identification and repair.

Duct Blaster Testing

Site visits also included duct blaster testing using a Minneapolis duct blaster assembly. Like the blower door, the duct blaster uses a calibrated fan assembly to measure leakage in the ductwork. Ductwork is the network of pipes that distributes conditioned air from the central HVAC system to the rooms of the house. Any leakage in the ductwork reduces the HVAC system's ability to provide conditioned air to the house. During the site visit, the fan assembly is attached to the return register of the HVAC system and all of the supply registers are closed off using a non-marring tape. The fan pressurizes the ductwork and a pressure gauge measures the total amount of leakage in the duct systems. Leakage typically occurs at connection points and the leaky areas often easily identified with a cursory inspection.

Baseline Energy Modeling

Baseline modeling involves entering all of the collected data from the site visit into a computer modeling program that estimates and predicts energy use. This process is used to calculate the HERS index, energy consumption, and operational costs associated with the existing building. The computer modeling program used by Sustainability Institute researchers is called the REM/Rate™ Energy Modeling Software. REM/Rate™ is a sophisticated residential energy analysis, code compliance, and rating software developed specifically for the needs of the Home Energy Rating System. The software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for both new and existing single and multi-family homes[9]. The climate data entered into the system is available for cities and towns throughout North America, making it customizable and more accurate as a result.

Using REM/Rate™, researchers were able to create a highly accurate baseline energy model that depicts the existing (baseline) energy use for the building. In an effort to maintain accuracy the computer energy model is quality controlled by a third-party

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[9] Architectural Energy Corporation, www.archenergy.com

qualified RESNET Quality Assurance (QA) provider. The QA provider verifies protocol was followed and verifies the accuracy of the baseline energy model. Once approved by the QA provider, the rater can begin the improvement analysis.

Improvement Analysis

Once a RESNET QA provider has verified the quality of the baseline model, researchers use the REM/Rate™ modeling program to simulate changes to the building and estimate the impact on energy consumption. The modeling program also allows for cost benefit analyses of suggested changes. Changes to the leakage rates, insulation levels, windows, and mechanical equipment are analyzed to determine which improvement component is most effective. By altering many different aspects of the building within the computer program, researchers can model anything, from changing insulation levels to replacing windows, without actually changing the structure itself. This virtual testing assures that only the most effective changes that will not substantially damage the historic fabric of the building will be made.

Reporting

The final step in the energy audit process is the production of an improvement analysis report to summarize the results. Every homeowner who commissions a HERS rating receives a personalized report indicating which retrofits are justifiable based on a cost benefit analysis. Homeowners can use the financial information from the report to prioritize improvements and as a guide for making repairs. The financial information in the report will also help to determine if a homeowner qualifies for an Energy Improvement Mortgage (EIM).

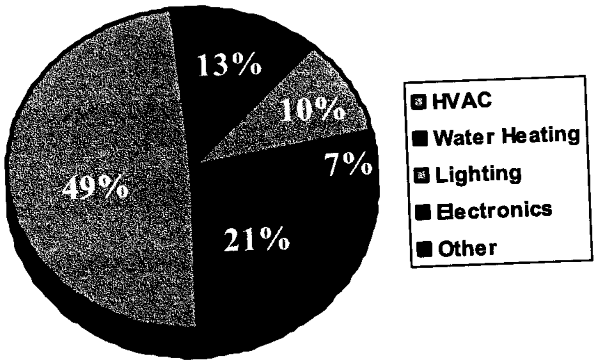
EIMs are a mortgage tool developed in the mid 1990's and are currently in use by all major lending institutions. Energy efficient mortgages allow homeowners to count energy savings as extra income. If the energy savings of the suggested improvements outweigh the improvement cost, the homeowner can refinance the improvements into a mortgage and use the energy savings to pay for the improvements. EIM's have not gained popular acceptance among lenders, due primarily to the extra steps required to qualify a customer. However, as HERS ratings become more popular EIM's will be more widely used by lending institutions. For more information about Energy efficient mortgages see the "Energy Ratings and Mortgages" section of the RESNET website: http://www.resnet.us/ratings/overview/default.htm

The improvement analysis report not only offers financial information related to suggested repairs but provides specific suggestions to contractors for the most appropriate methods for repairs and rehabilitation. Building professionals, such as contractors and architects, can use the report as a guide during the rehabilitation process. Any simulated modifications to the historic buildings include only those that follow the *Secretary of Interior's Standards for Rehabilitation* and are justifiable to the average property owner. As a result, recommendations are guaranteed to be practical, cost effective, and historically sensitive. Information in the report should be especially helpful to HVAC technicians as the report provides analysis of envelope and duct leakage and the insulation levels (both existing and recommended). This information is needed to properly size and install an effective HVAC system. Furthermore, the report provides industry best management practices to ensure that the repairs are completed in a way that protects the building from damage.

In a climate such as Charleston's, contractors must make sure adequate attention is paid to moisture control, insulation, and air sealing to prevent damage to the building. Understanding the dynamics of heat flow, pressure, and moisture transmission will assure proper installation of materials to prevent damage to the historic building assessed. The improvement analysis report offers building specific details of how repairs should be conducted to avoid potential for problems in the future. The following section will address the science behind how buildings operate so the reader can understand and avoid common pitfalls of building rehabilitation.

Foundations of Building Science: The Energy Profile

Increasing energy efficiency begins with an understanding of residential energy use. The home energy profile illustrated in the figure below shows the typical end uses of energy in a home. The energy profile helps to establish the best areas to target for energy efficient improvements.

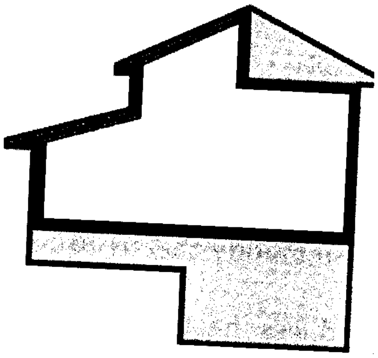


Source: The Energy Information Administration

Almost half of residential energy is consumed by heating, cooling and ventilation systems (HVAC). Energy use from water heating, lighting, appliances, and electronics respectively make up the remaining components of the energy profile. Improvements to each of these components should be based on impact, practicality, and cost. In a historic home, energy efficiency is achieved through successful management of the energy profile components. Because heating, ventilation, and air conditioning comprise the majority of a home's energy use, it is often the best point of attack when attempting to reduce residential energy consumption.

The House as a System

Heating, cooling and ventilation comprises the majority of energy use in a home. This is partly due to the efficiency of the equipment we choose but also because of the efficiency of the building envelope. The phrase "building envelope" is a term describing the walls, floors, and ceilings that separate conditioned and unconditioned spaces. Homes with a well-sealed and well-insulated envelope are easier to heat and cool. As a result, energy consumption and energy bills are lower. The building envelope is responsible for keeping conditioned air inside the house and outside air from penetrating indoors. Focusing on building envelope improvements is often the most effective and least expensive method for increasing energy efficiency.



***The building envelope** is the highlighted area on the edges of the structure (Source: Southface technical bulletin)*

An effective building envelope consists of four main components:

- **Air Barrier**- An air barrier stops convective heat flow by inhibiting air from infiltrating the building.
- **Thermal Barrier**- A thermal barrier stops conductive heat flow by providing insulation from heat flow.
- **Radiant Barrier**- A radiant barrier inhibits the absorption of heat energy by reflecting the energy away.
- **Moisture barrier**- A moisture barrier inhibits moisture transfer.

The Air Barrier

A successful air barrier seals the house tightly and inhibits air leakage. Examples of air barriers include any building material that prevents the flow of air (plaster, caulk, weather-stripping, etc). In a hot-humid climate like Charleston, S.C., air leakage is one of the most important factors impacting energy efficiency. Infiltrating air reduces efficiency by allowing heat and humidity to filter into the building envelope. The introduction of warm, moist air causes a home's HVAC system to work harder to condition and dehumidify the air to reasonable levels. Sealing and creating a tight building envelope reduces heat gain and moisture infiltration and can drastically increase efficiency. Retaining the integrity of the building envelope, specifically the air barrier, is the combined responsibility of many tradesmen, from framing contractors to plumbers. Each member of the building team is partly responsible for maintaining low leakage rates. With no central responsibility for maintaining air tightness, air leakage often goes unchecked and unabated.

The blower door test measures how effectively the building envelope provides a barrier to air infiltration. The blower door measures infiltration in air changes per hour (ACH). This can be thought of as the percentage of the indoor air that escapes per hour. The standard American home may have 65%-100% ACH under natural conditions, meaning that 65% to 100% of the conditioned air in the house is lost through the building envelope every hour. A house with a well-sealed air barrier may have less than 35% leakage.

Historic homes often have leakage rates well above 100%. This high level of leakage creates a building envelope that allows massive amounts of heat flow and moisture intrusion through the process of convection. This leakage can compound energy and moisture problems because larger HVAC systems are required to overcome the high level of heat and humidity transfer in historic buildings. Depending on how well an HVAC system is installed, it can effectively condition the indoor environment of the house, but at great cost both in energy consumption and utility bills.

A more effective approach consists of making repairs to the air barrier first, then installing an HVAC system. Reducing heat and moisture transfer first by repairing the building envelope increases comfort and reduces the heating and cooling load, thereby saving energy and reducing utility bills. In addition, future HVAC systems will not have to be as large to overcome heat gain in the building.

Green building standards like Energy Star, EarthCraft House, and LEED for Homes have embraced the idea that a solid and well-sealed air barrier is the first step towards energy efficiency. As a result, all of the green building standards mandate a maximum allowable leakage rate allowed to certify a home as energy efficient and "green". To achieve certification under a green building standard, contractors must limit the home's air leakage to an absolute minimum. In existing homes, an effective air barrier may offer the cheapest and easiest means to reduce the strain on the HVAC system and consequently reduce energy consumption. Simply by locating and sealing holes in the building envelope with caulk, spray foam or other air sealing measures the home becomes easier to condition and energy costs decline.

The Thermal Barrier

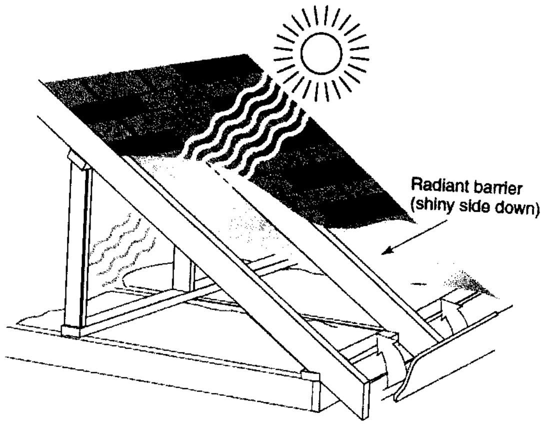
The thermal barrier controls conductive heat flow, which is heat transferred through solids. An effective building envelope will resist the flow of conductive heat using insulation. The "R" in "R-Value" describes the level of resistance insulation provides from heat flow. The higher the R-value, the greater the resistance to heat flow. In Charleston's climate, the recommended level of wall insulation is R-13. However, areas with extreme temperature differentials like attics and crawl spaces require higher insulation levels to properly maintain comfort. To provide an effective thermal barrier, the current energy code suggests R-30 insulation in the ceiling and R-19 in floor systems and knee walls.

Insulation is often confused as an air barrier. However, it is important to realize that insulation alone will not stop airflow. With only insulation in place, convective heat and moisture can flow unabated through the building envelope through air currents. The most effective thermal barrier should be installed without gaps or compressions and in direct contact with an air barrier discussed in the previous section.

In any home, but particularly a historic home, attics and crawl spaces are the best places to start when considering retrofitting options. These assemblies harbor the most extreme temperature differentials and therefore require elevated insulation levels. These spaces are often readily accessible through access hatches and can be upgraded easily. Wall systems, in contrast, require extreme modification to retrofit insulation. In many cases, installing insulation in wall systems is a costly, invasive, and destructive process. Historic interior fabric such as plaster and woodwork are often lost to this type of renovation. Therefore, improvements to the thermal barrier should focus on attic and crawl spaces first, because this does not impact the historic fabric of the building.

Radiant Barriers

Radiant barriers reflect heat energy. In construction applications, these barriers are often installed as films in an effort to reflect the sun's radiant heat away from the building and prevent heat gain. Most radiant barriers are thin sheets of reinforced aluminum. In attics, radiant barriers can be installed on the underside of the roof to limit the absorption of heat energy. Under normal situations, the sun's energy strikes the surface of the roof. The roof warms and radiates the heat downward into the attic, increasing heat gain. A radiant barrier installed on the underside of the roof will prevent the heat gain in the attic by reflecting the energy back up through the roof. Radiant barriers have potential to reduce attic temperatures and increase the effectiveness of attic insulation. For more information about radiant barriers see the "Radiant Barriers" fact sheet from the Southface Energy Institute:



Radiant barrier installed to rafters
(Courtesy of Southface)

http://www.earthcrafthouse.com/documents/factsheets/14radiantbarriers.pdf

Moisture Barriers

Moisture control is often one of the most important and misunderstood duties of the building envelope. It is also one of the most difficult components to manage within the building envelope. The building envelope keeps us safe from inclement weather and water intrusion and avoids problems associated with rot and mold. The building envelope is comprised of several barriers to control moisture effectively.

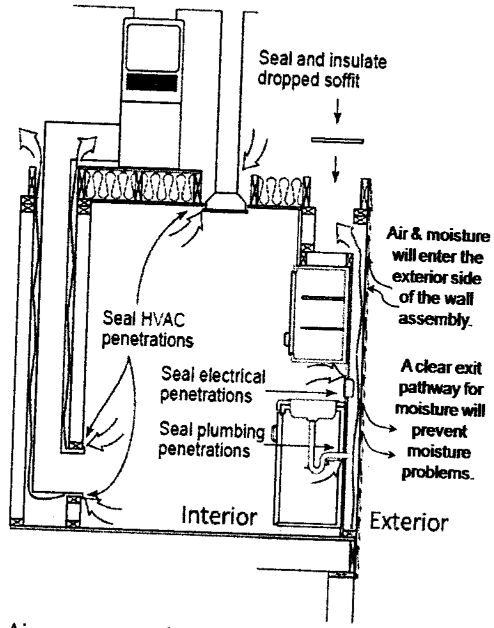
A *weather barrier* controls bulk moisture, such as rain or snow, and shelters the occupants of the house from the elements. Weather barriers can take the form of siding or roofing shingles. An *air barrier* prohibits the infiltration of moisture transferred by convection. This barrier prevents moisture intrusion in the form of humidity by limiting air infiltration. The air barrier is represented by air sealing components like caulking or weather-stripping or building components like plywood or drywall.

Condensation is another problematic issue for historic buildings. Collectively, weather and air barriers can help prevent moisture problems due to condensation. In many historic Lowcountry homes, condensation occurs on the interior surfaces such as, windows, HVAC registers, floors and even entire walls. If left unchecked, the excess moisture can cause mold, rot, and structural issues unless efforts are made to prevent condensation. To prevent moisture problems related to condensation, it is important to understand the physics of moisture dynamics.

Simply speaking, warmer air can hold more moisture than colder air. The condensation process occurs when central HVAC systems cool ambient air and interior surfaces of the home. As the air is cooled, it loses its ability to hold water and condensation forms on the interior surfaces of the home. One may experience this same process drinking a glass of iced tea on a warm summer day. Warm, moist air encounters a cold surface of the glass and condensation forms on the glass. In a construction application, the condensation is deposited on the interior surfaces of the home such as HVAC registers and windows.

For condensation to occur, warm, moist air must encounter a cold "condensing" surface. As it is nearly impossible to remove cold surfaces from the home, the standard approach to preventing condensation in homes has been to remove the warm moist air from the home, thereby preventing condensation. For most houses, the central HVAC system can accomplish this task. However, many historic houses are so egregiously leaky that the HVAC system may not have the capacity to remove all of the humidity from the air. The standard procedure to fix this problem has been to install whole-house dehumidification systems. This additional mechanical equipment may effectively remove moisture, but it will also drastically increase energy consumption and utility cost.

A better approach for preventing this problem lies not in removing moisture from the house, but in *preventing* moist air from entering the building. Preventing air infiltration, with the installation of an effective air barrier, reduces the amount of humidity in the indoor air environment. As a result, condensation is less likely to occur and moisture issues are drastically reduced.



Air movement through a typical historic wall assembly (adapted from Southface Factsheet)

The concept of air sealing a historic home causes concern for many builders and preservation-minded individuals due to the belief that air sealing a house may trap moisture inside wall, floor, and ceiling assemblies. In the past, builders have gone to the extreme and have attempted to seal historic buildings using techniques like caulking all of the seams in exterior siding, removing attic ventilation, and even going so far as to wrap the entire house in a plastic vapor barrier. These techniques can potentially trap moisture within wall assemblies and cause mold, rot and deterioration of the home's historic fabric. Though well meaning, the ill fated attempt at air sealing could very easily cause damage to the building.

The figure to the left depicts the movement of air through a typical wall assembly. Air and moisture can easily infiltrate into wall cavities through gaps between siding, around windows, doors and the many other exterior bypasses of the building. Without a clear pathway out of the wall cavity, the infiltrating humidity can become trapped and cause a moisture problem. To avoid trapping moisture and causing damage, air sealing should occur on the *interior* of the house.

The goal of air sealing should be to prevent air and accompanying humidity from entering the conditioned spaces of the house. Common interior pathways for this infiltration are plumbing, electrical, and HVAC penetrations like shown in the picture at the left. As buildings settle and age, gaps and cracks also form in ceilings, walls and floors. In laymen's terms, if there is a hole, fill it, patch it, fix it, or otherwise have it repaired in an effort to stop air from entering the building through that space. Sealing these penetrations prevents the infiltration of unconditioned air and the loss of conditioned air. As a result, the building is easier to heat and cool and energy consumption is reduced.

Capillary action presents an additional means for moisture to transfer into building components. Flowing from wet areas to dry, moisture can transfer, or wick, from the ground into porous building materials like brick or wood. Capillary action can cause brick foundations and wood framing to absorb and retain moisture within the walls floors and ceilings of a building.

A *capillary break*, like a termite shield or sill sealer, will prevent moisture transfer from the ground to building materials. Weather, air, and capillary barriers are important in all climates to prohibit moisture intrusion in buildings.

The Vapor Barrier

Moisture, in its vapor state (gaseous) comes typically in the form of humidity. An area with high humidity is said to have a high concentration of water vapor molecules. Moisture will naturally travel from high concentrations to low through a process called diffusion. In the built environment, the diffusion process occurs regularly when a moisture differential exists across the building envelope. During summer months, conditioned building interiors are typically less humid than the ambient air. This causes the outside air to have a higher concentration of moisture. Because of this differential, moisture will naturally diffuse into the building. During the winter heated air can produce the opposite effect—the conditioned air is warm and moist and the moisture will diffuse to the exterior of the house.

A vapor barrier impedes the flow of vapor molecules and slows the diffusion process. Installed correctly, the vapor barrier should be facing the high-pressure area (towards the heat and humidity). If Charleston's climate were warm and moist 100% of the time, a vapor barrier would be effective if installed facing the exterior of the house only. However, Charleston winters, though mild, provide instances where the inside of the home is warmer and moister than the outside. These environmental variables can cause moisture to be trapped on the inside of wall systems. If left unchecked, the excess moisture can cause mold, rot, and structural issues.

Therefore, it is best to not install a vapor barrier in historic houses in Charleston. Though moisture will find its way into wall systems, without a vapor barrier it will have a clear exit pathway so that the wall system is less likely to be compromised by mold, rot, or other moisture issues.

Beyond the Building Envelope: Heating, Ventilation, & Air Conditioning (HVAC)

The modern household uses mechanical equipment to condition the indoor environment to comfortable levels. The application of heating, cooling, and ventilation at various locations maintains the comfort of building occupants by controlling air temperature, humidity, air flow, and the temperature of the surrounding surfaces of the house interior. As described in the previous section, it is most important to provide for a sound building envelope. After this is established, mechanical equipment should be sized and installed correctly.

Sizing

Correctly sizing mechanical equipment begins with an HVAC load calculation. The load calculation determines the capacity, or size, of a heating and cooling system required to overcome the indoor environmental variables. The Air Conditioning Contractors Association (ACCA) has established standards to determine how many tons of heating and cooling are needed based on building variables such as square footage, building orientation, infiltration rates, insulation levels, climate, internal loads, and ventilation requirements.[10] Over-sizing HVAC systems can complicate moisture issues by limiting a system's capacity to remove moisture from the indoor air environment. An oversized system is prone to short cycling- a process by which the system activates, quickly cools a space, and deactivates in a short period of time. Short cycling can cause moisture issues because dehumidification may not be possible within so short of a time frame. This process may cause comfort issues, higher utility cost, and may shorten the useful life of equipment.

The historic elements of a home can be compromised by inappropriately sizing an HVAC system by exacerbating the condensation process described above. At a minimum, HVAC contractors should use the *Manual J* load calculation (established by the ACCA) to size the mechanical equipment based on an established protocol. Sizing systems based on "experience" or rules-of-thumb should be avoided. [11]

Ductwork

Ductwork is the series of pipes that carry conditioned air from the HVAC system to the rooms of the building. Correctly sizing ductwork will allow the proper volume of air to reach the intended spaces. Contractors should install ductwork to be as short and straight as possible. Kinks, bends, and long runs in the ducts will inhibit the flow of air

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[10] These variables, among others, are calculated in the ACCA's "Manual J" load calculation procedures.

[11] "Right-Size Heating and Cooling Equipment Technology Fact Sheet", Southface Energy Institute, www.earthcrafthouse.com/documents/factsheets/RS-Right-size_HVAC 02-1490.pdf

and will cause pressure imbalances in the house. This can lead to comfort issues, burgeoning energy consumption, and potential indoor air quality issues.

The duct system must also be free of leaks. Leaky ductwork is one of the largest drains on energy in residential construction. Up to 20% leakage is typical in an HVAC installation. With that high degree of leakage, an HVAC system's efficiency can be cut by 50%! Having no duct leakage would be ideal; however, this is impossible unless the HVAC system is installed completely within the conditioned spaces of the house. When HVAC systems are installed in attics or crawl spaces, a reasonable goal for any system should be 4%-6% leakage based on square footage served by the system.

Summary

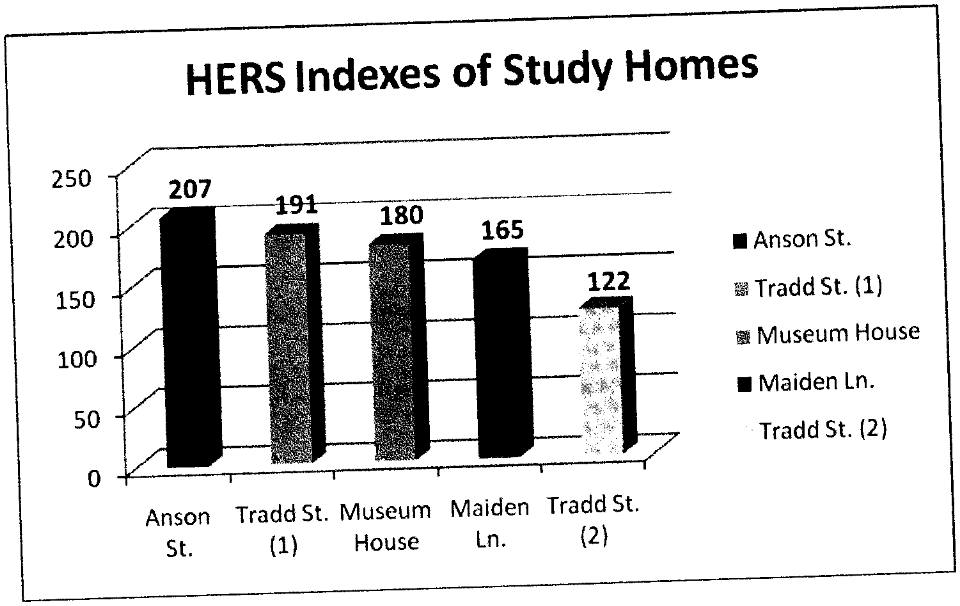
Collectively, envelope improvements and proper installation of HVAC systems can drastically reduce energy consumption in a historic home. Based on impact and practicality, these improvements are often the least costly and offer a beneficial return on investment. Contractors can easily manage air leakage, insulation levels, and duct leakage within the confines of the *Secretary of the Interior's Standards for Rehabilitation*. With proper installation, tremendous reductions in energy use can be realized while renovating in a historically sensitive manner.

Case Study Results and Conclusions

Researchers tested and analyzed five historic structures in the Charleston area in an effort to better understand trends in the energy use and performance of residential buildings in Charleston. The ages of the buildings range from the mid-18th century to the early 20th century, with an average construction date of 1831. The size of the buildings varies as well, but they are generally around 3,500 square feet. Four out of five of the homes were located in downtown Charleston. Houses one and two are located on Tradd Street (Tradd St. 1 & Tradd St. 2); houses three and four are located on Anson Street and Maiden Lane respectively. The fifth house in the study is located outside of the downtown area and is currently being used as a museum house for guided tours. Most buildings in the study set are brick masonry construction; however, Tradd St (1) is a wood-frame building. The testing results of these structures and their implications are discussed below.

HERS Index Ratings of Case Study Buildings

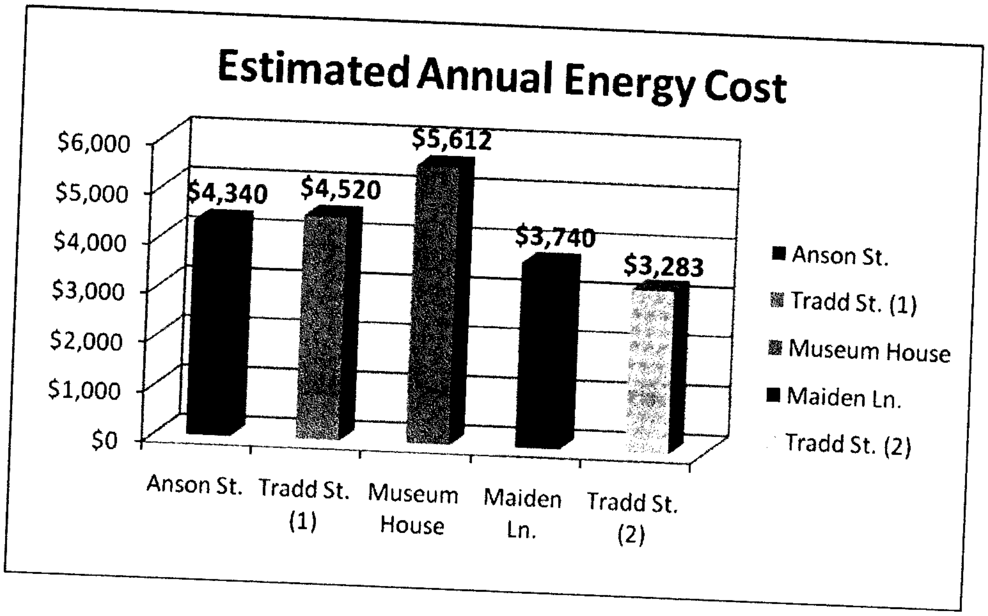
The Home Energy Rating System (HERS) index for each structure in the study is shown in the following graph. This HERS index is a measure of overall efficiency based on the protocol set by the Residential Energy Services Network. Higher index ratings indicate reduced efficiency. The average new American residence has a HERS rating of 100, while the average existing building rates around 130. The average HERS index of this study set is 149, indicating that, on average; the historic homes in this study are 49% less efficient than the typical new American residence.



The Anson Street home has the highest index rating, primarily due to extreme duct leakage. Researchers found a detached HVAC duct during the site visit, which was causing massive amounts of duct leakage and drastically reduced efficiency. Tradd Street (2), in contrast, yielded an index of 122, indicating that the home is 8% more efficient than the average existing American home. The lower HERS index of the residence at Tradd St. (2) indicates that achieving efficiency levels on par with the average existing home is indeed possible.

Estimated Annual Energy Costs for Case Study Buildings

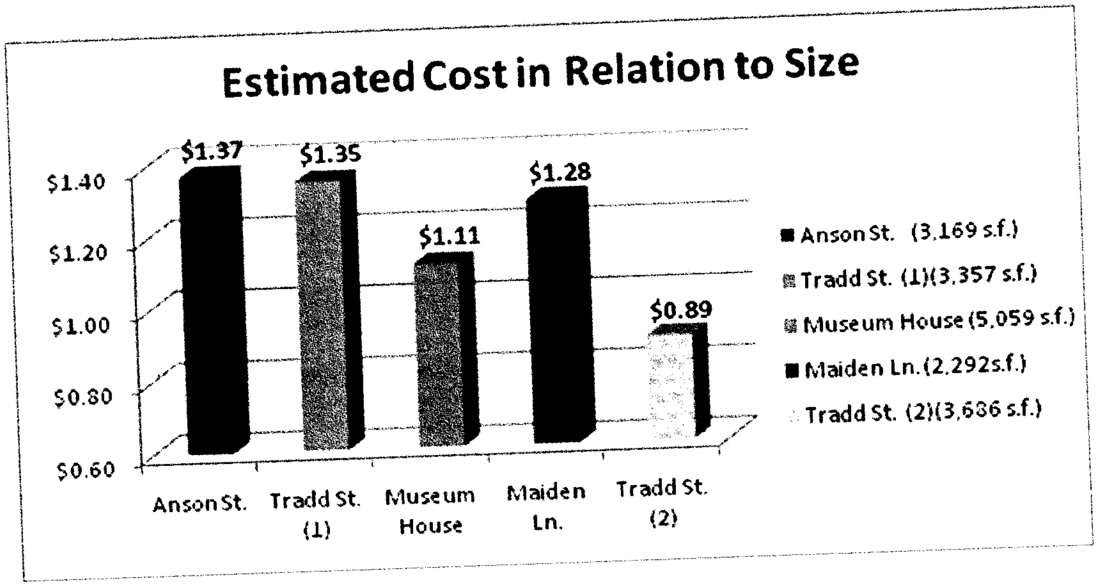
The graph below shows the estimated annual energy costs for each building as determined by the REM/Rate energy model. The model estimates energy use based on assumptions made about occupancy levels and typical human behavior.



Tradd Street (2) experienced the lowest energy costs in the modeling process primarily due to low levels of envelope leakage and proper insulation levels. The Museum House energy model produced the highest estimated energy costs. This high cost is likely due to the size of the building as compared to the others in the study—the Museum house is more than 5,000 square feet of conditioned floor area making it more than 1,775 square feet larger than the average square footage of the other buildings in the study.

Cost in Relation to Size for Case Study Buildings

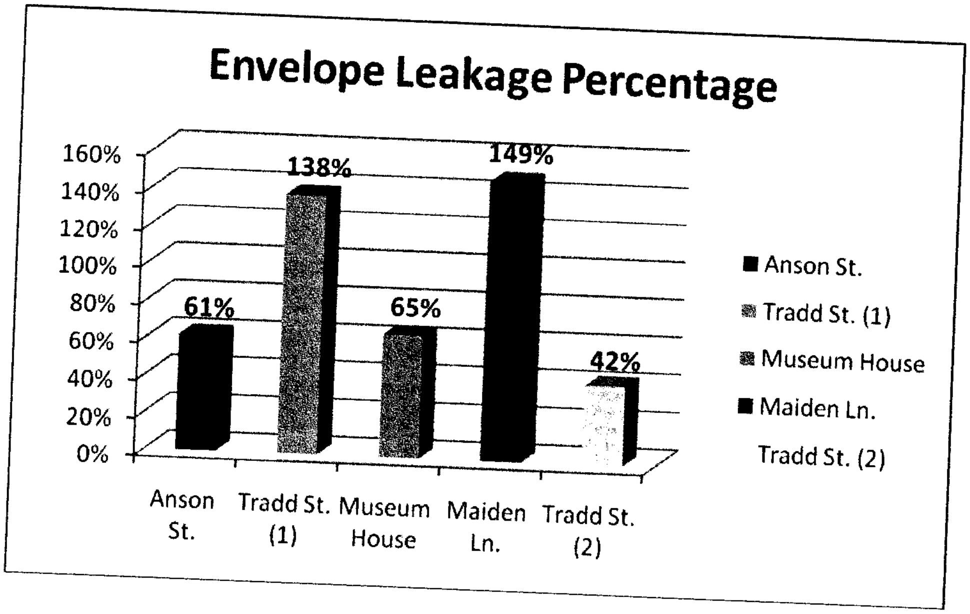
The figures below show the square footage and energy cost per square foot for each of the buildings in the study. Because the houses varied in size, normalizing based on square footage allows for a better comparison of the energy cost across the case study.



As is shown above, the cost varied quite significantly, ranging from $0.89 per square foot at Tradd St. (2) to $1.37 per square foot at the Anson St. House. Tradd St. (2) still ranks as the most efficient of all of the homes in the study. Again, this is likely due to the well-sealed and well-insulated building envelope. Using this reporting method, the Museum House's cost per square foot indicates one of the lower rankings. The Anson St residence, in contrast has the highest cost per square foot, likely due to the aforementioned extreme duct leakage.

Envelope Leakage Levels in Case Study Buildings

The envelope leakage figures indicated below are based on the blower door testing conducted on each of the buildings. This pressurization test indicates the specific leakage ratio for each tested structure in percentage of air volume exchanged under natural conditions. Homeowners should seek to achieve a 35% level of envelope leakage which is recommended by many green building standards.

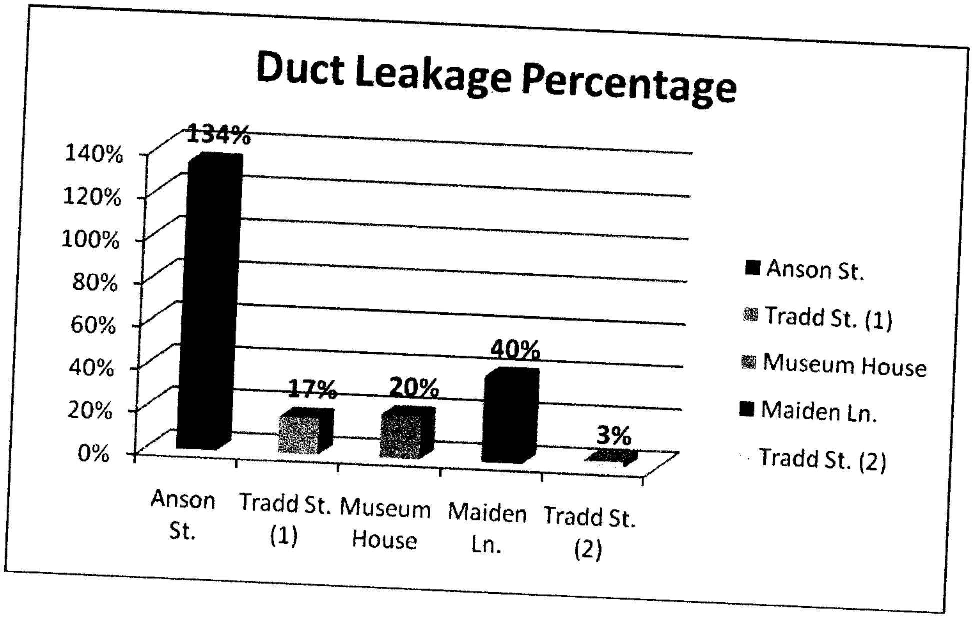


The Maiden Lane residence experienced the highest level of envelope leakage at 149%. This level of leakage suggests that 149% of the indoor air is lost through holes in the building envelope every hour. The level of envelope leakage experienced in the Maiden Lane and Tradd St. (1) residences is greatly responsible for the increased energy consumption in these buildings. In contrast, the Tradd Street (2) residence has an extremely low level of envelope leakage (42%), even when compared with a new American home. Low levels of envelope leakage contributed to the low heating and cooling costs for this building by reducing the load on the HVAC system.

There were no notable moisture problems in the Tradd St (2) residence. The envelope leakage data suggests that low levels of leakage are achievable in a historic building without causing moisture issues or compromising the historic integrity of the building. Further research is necessary to definitively evaluate causes of moisture problems in historic houses though this research suggests energy efficiency gains can be effectively made by properly air sealing the building envelopes of historic houses.

Duct Leakage in Case Study Buildings

The duct leakage figures indicated below are based on the duct blaster testing conducted during site visits. A duct blaster pressurization test indicates the level of leakage in the duct systems. The level is expressed as a percentage of air lost to the outside of the building shell based on the square footage served by the system. Leakage levels between 4%-6% are acceptable for ductwork installed outside of the conditioned spaces of the house. Air leakage through the HVAC ducts is a major problem in many residential structures, modern or historic. The graph below depicts the levels of leakage experienced by the homes in this study.

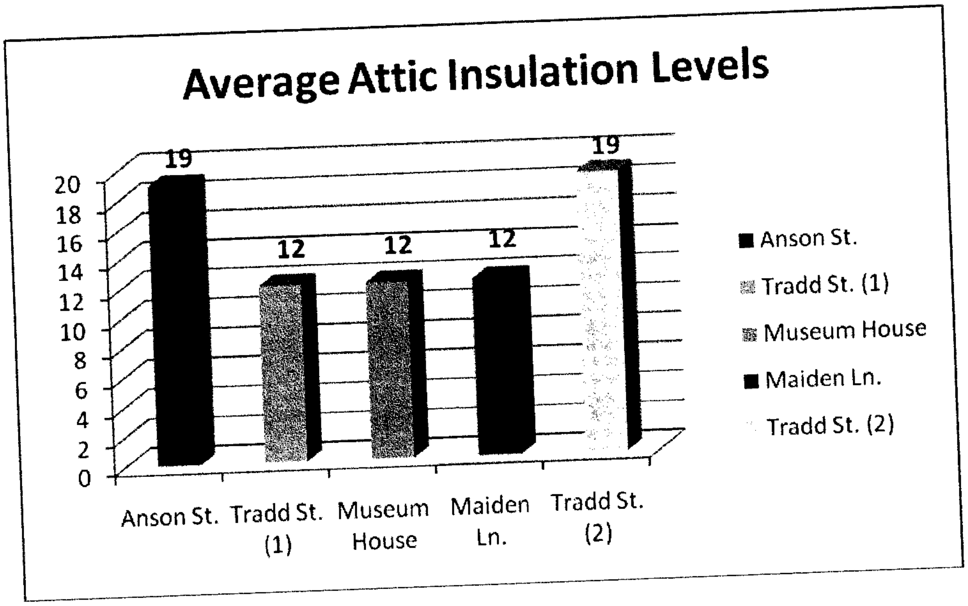


Duct Blaster testing on the duct systems at the Anson Street residence revealed extremely high levels of leakage. This data point is an extreme outlier and is not typical of the homes in the study. In the case of this residence, a duct had broken loose from the system and needed immediate repair. The residence at Tradd Street (2), again, exemplifies the level of energy efficiency that can be achieved through careful, accurate installation of HVAC components. A 4% duct leakage is the goal for all residences. It is rare that leakage levels less than this figure are found in duct systems installed outside of the building envelope. However, the 3% leakage level found in the duct systems in Tradd Street (2) indicates the HVAC contractor took special pains to dramatically seal the duct systems. As a result, the corresponding HVAC system runs more efficiently and energy consumption is reduced.

The data from Tradd Street (2) further suggests the efficiency capability of historic structures. Low levels of leakage found in this building's HVAC system indicate an area for efficiency gains that do not cause adverse impacts to the historic integrity of the building. Homeowners should expect the attention to detail exemplified by a responsible tradesman at Tradd Street (2). Duct blaster testing can help to assure this attention to detail during the HVAC replacement process. Homeowners can ask for a guarantee of 4% leakage or less from HVAC contractors. By commissioning a duct blaster test after work is complete, the homeowner can ensure that their contractor meets an appropriate level of quality.

Attic Insulation Levels in Case Study Buildings

Insulation levels in attics and floors have a heavy influence on the energy efficiency of the building. The graph below depicts the average R-value, or level of insulation, found in the attics of each building within the study. Greater amounts of insulation in an attic spaces provide greater protection against heat gain through the ceiling.

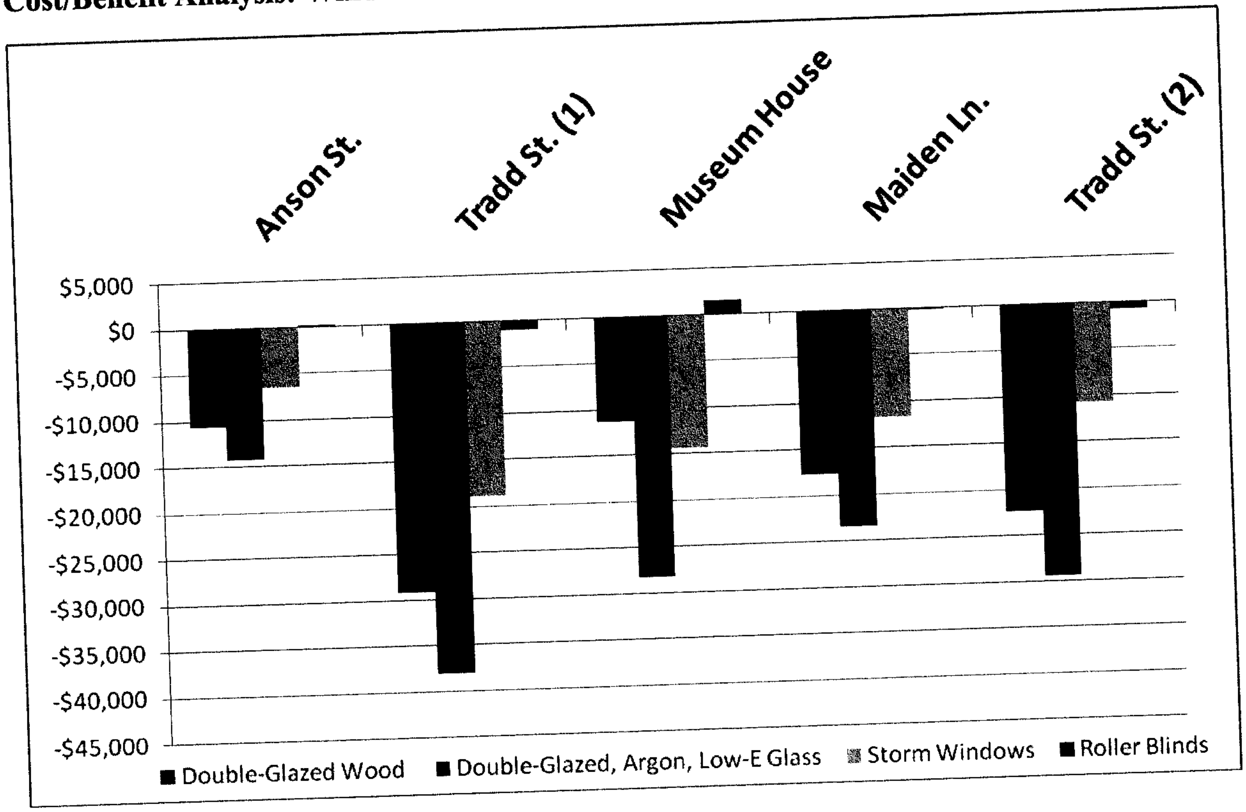


Though the insulation levels vary between the buildings in the study, it should be noted that none of the buildings had insulation levels on par with the current building code recommended level of R-30. This represents an easy upgrade that can be performed within the confines of historic preservation principles without any adverse impacts to the historic character of the building.

Cost/Benefit Analysis: Windows

Windows are often a contentious topic from a historic preservation perspective. Homeowners often wish to replace windows because they have been told that new windows will help to reduce energy costs. While replacement windows *can* reduce energy costs, a homeowner needs to be certain that the expected savings will outweigh the cost of improvement. The following graph depicts the net monetary loss from window replacement in the study set. Based on the analysis in this study, window replacement would not produce a positive cost benefit to the homeowner in any of these homes. In all cases in this study, the high cost to replace historic wood windows with modern double-glazed wood windows surpassed the resulting energy savings over the useful life of the window.

Cost/Benefit Analysis: Windows



Double-glazed wood windows are perhaps the least obtrusive window replacement if a property owner desires to replace the existing historic windows. However, the decision to replace existing windows of the homes in the study would never yield a positive return on investment. The net monetary loss for a double-glazed wood window replacement ranges from $10,686 to $29,210 within the homes in the study.

Double-glazed, argon gas filled, low-E windows are perhaps the most energy efficient windows on the market at the time of this study. However, the graph shows that in all study buildings, the high cost of replacing the existing windows does not rival the smaller cost savings created from reduced energy use. The net monetary loss for a double-glazed, argon gas filled, low-E window replacement ranges from $14,216 to $38,035 within the homes in the study.

Storm windows are certainly a better option for window improvement, and their installation does not require the removal and replacement of the historic window assembly. However, as the above graph shows, in all of the properties in this study the cost to add storm windows to all of the existing fenestration costs more than the energy savings received from the retrofit. The net loss for a storm window addition ranges from $6,556 to $18,952 within the homes in the study. Also, storm windows are typically not allowed by the Board of Architectural Review in the historic district of Charleston.

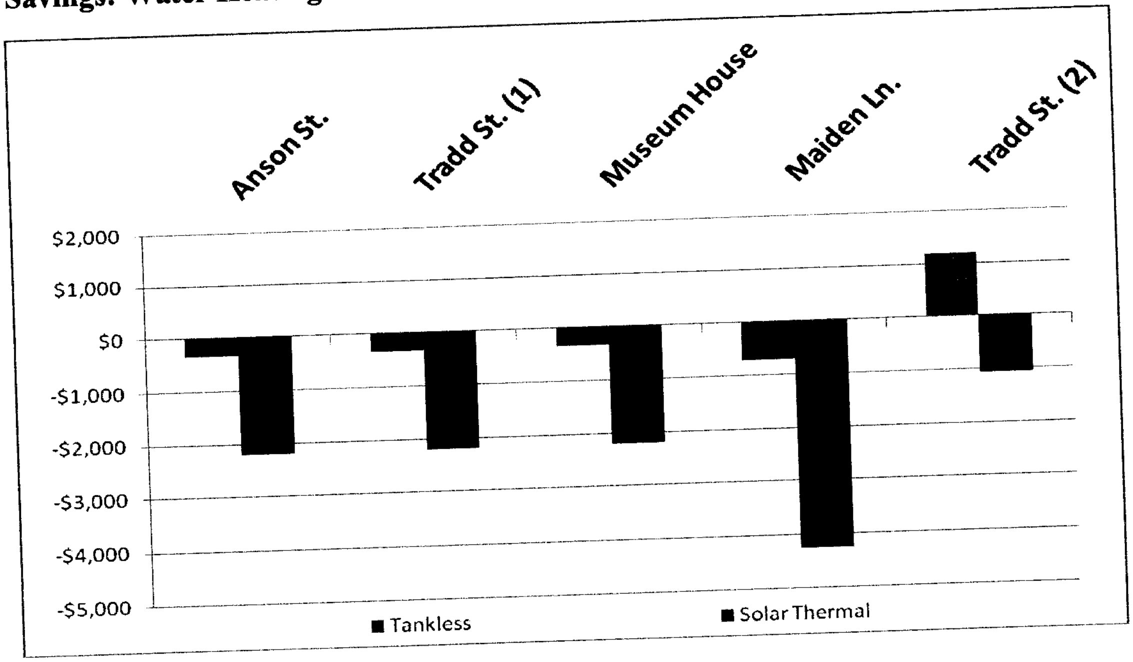
Increasing the shade factor on windows greatly reduces the amount of heat gain a building receives. For example, white, opaque, roller blinds are an inexpensive retrofitting option that can make a significant difference without damaging a historic window. The roller blinds block or reflect a significant portion of the sun's radiant heat, as a result, less heat is gained in the house, and the homeowner saves on heating and cooling costs. In two buildings in the study, Anson St. and the Museum House, the addition of roller blinds to the historic windows offers a positive return on investment. However, in the remaining buildings in the study the roller blind addition yields a net loss ranging from $188 to $1,093.

The window data suggests that homeowners should never replace windows based solely potential energy savings. Instead, window replacement should occur in situations where the window cannot be repaired to function properly. Following this procedure will ensure that the homeowner rehabilitates a historic home as cost effectively as possible while protecting the historic windows.

Net Savings: Water Heating

The graph below depicts the net monetary savings/loss that results from upgrading water heating units to more efficient models, such as tankless water heaters or solar power. Each of the homes in the case study had traditional tanked models of water heaters. These units heat water continuously in a tank at a specified temperature, regardless of the call for hot water. In contrast, a tankless model actively heats water only when called for by a user. Tankless models drastically reduce standby energy loss and have higher efficiencies than traditional tanked systems.

Net Savings: Water Heating



Only in the case of the residence at Tradd St. (2) did a tankless retrofit make sound financial sense. However, these figures may change with a larger sample size. Due to the high cost of tankless water heaters, replacement of these fixtures should not be based on energy savings. A homeowner should wait until replacement is necessary and then upgrade to a tankless system.

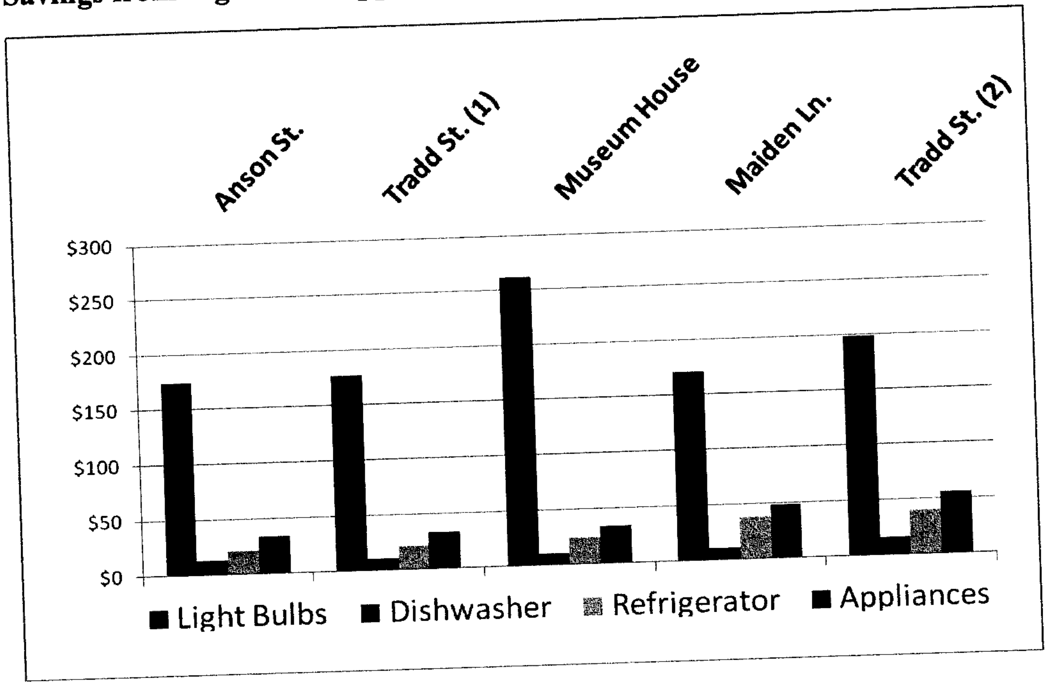
Using solar panels, solar thermal water heating systems preheat water before it enters a storage tank. In our climate, the solar panels are capable of producing enough hot water so that auxiliary tank water heating is virtually unnecessary. In each of the cases, a solar water heater reduced water heating costs to zero. However, due to the high cost of replacement, the replacement did not return a positive return on investment.

Tax incentives are available to reduce the installation costs of solar water heating by 60%. These incentives depend greatly on the homeowner's level of income and tax structure, so these figures are not included in this report. A larger sample size may reveal cost-effective opportunities for solar water heating.

Energy Savings from Lights and Appliances

Energy consumption from lighting and appliances typically comprises the second largest user of energy in the average American household. Changes to lighting and appliances are not usually constrained by historic preservation principles, so upgrading to more efficient lighting strategies or appliances are often easy for a homeowner to accomplish.

Savings from Lights and Appliances



Replacing light bulbs with equivalent compact fluorescents (CFL) yields the greatest savings to investment ratio of all of the improvements in this report. Based on the relative low cost of investment, the CFL replacement is a sound financial investment across all of the homes in the case study.

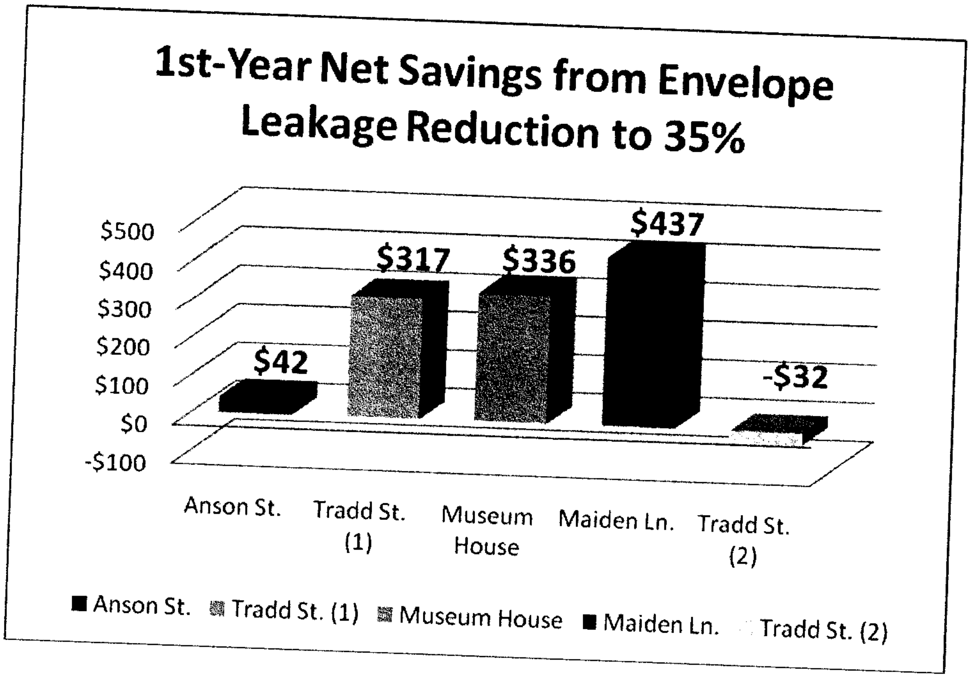
Upgrading kitchen appliances to Energy Star-rated machines can provide savings in energy consumption. The above graph shows the effect of each of these retrofits for each house in the study. The term "appliances" refers to the combined effect of upgrading the dishwasher and refrigerator at the same time. Due to the high cost of appliances, replacement of these fixtures should not occur based solely on energy savings. A homeowner should wait until replacement is necessary and then upgrade to an Energy Star Rated appliance.

Savings Figures for Suggested Repairs

The following sections analyze the savings associated with recommended repairs of historic homes. Each of the recommendations follows the *Secretary of the Interior's Standards for Rehabilitation.*

First Year Net Savings: Reductions in Envelope Leakage

The following graph depicts the net savings from air sealing the building envelope to a significant level. This type of repair can include caulking, spray foaming, and weather-stripping around windows and doors, as well as blocking large holes in the envelope with sheet goods like plywood, sheet rock, or foam board insulation. The recommended level of leakage is 35% based on the interior volume of each house. The following chart shows the estimated energy cost savings from reducing envelope leakage to 35% after the first year.



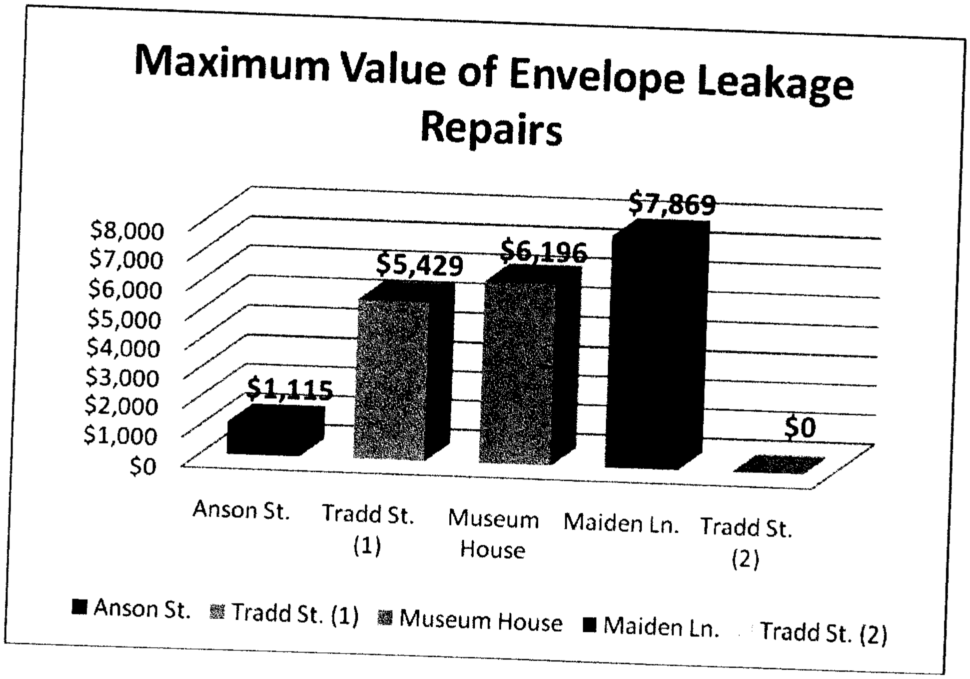
Depending on the current level of envelope leakage, the investment may be better suited to some structures more than others. For instance, the envelope leakage at Tradd St. (2) was already so low that reducing the envelope leakage further made little difference to that building's energy costs. In the case of this building, the cost of the repairs outweighed the benefit. As a result, researchers do not recommend further reductions in envelope leakage at this property.

Blower door testing was not performed on the Museum House. The Museum curators felt that the testing procedure would cause damage to the historic collection. As a result, a stand in value of 65% leakage was used for the estimates based on RESNET protocol. Sixty-five percent envelope leakage rate is not the worst possible result, but it is considered the maximum allowable leakage by current building codes.

Of the remaining residences, Maiden Lane could reap tremendous benefits from reduced envelope leakage. Maiden Lane recorded almost 150% envelope leakage during pressure testing. As a result, air sealing has the potential to dramatically reduce energy consumption at minimal cost. This repair is also financially advantageous for the Anson St. and Tradd St. (1) residences.

Maximum Value of Envelope Leakage

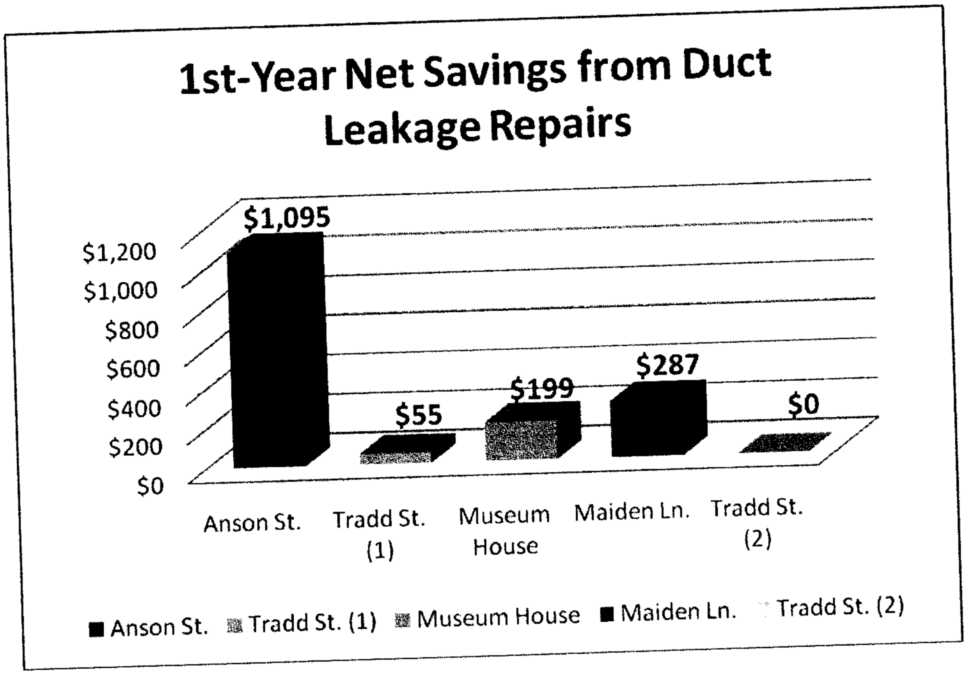
One of the greatest concerns property owners have when retrofitting their buildings is the cost of the changes. "Present Value" describes the future value of an upgrade in today's dollars. More specifically, present value depicts the maximum amount of money a homeowner can spend on an improvement and still have a positive return on the investment over the life of a 30-year mortgage. While many alterations have the potential to provide significant energy savings each year, the cost to make that change must be proportionately smaller than the energy savings to provide any realized gain. Present value offers perspective to the homeowner as to the maximum worth of any particular improvement. The following graph depicts the maximum value of envelope leakage repairs- the maximum amount a homeowner can spend on improving envelope leakage and still have a positive return on their investment.



Tradd Street (2) already has low levels of envelope leakage. Repairs to the air barrier are not viable because the cost of any repair outweighs the benefit. As a result, its maximum value is zero. The remaining homeowners could benefit dramatically from improvements to the air barrier. Homeowners at the residence on Maiden Lane could spend up to $7,869 on envelope leakage improvements and still break even financially.

First Year Net Savings: Duct Leakage Repairs

The following graph depicts the First year savings from duct leakage repairs. These figures assume the repair costs will be amortized over the life of a 30-year mortgage. The following graph depicts the net savings from reducing duct leakage to 4% based on the square footage.

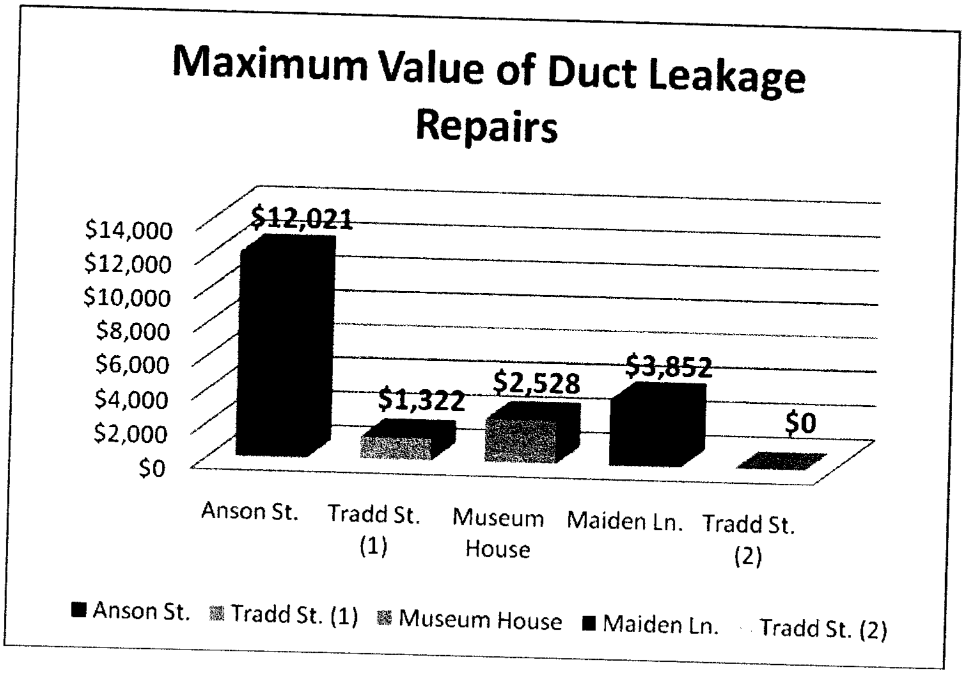


The duct leakage in the mechanical systems at the Tradd St. (2) already measured below the 4% level. As a result, the net savings and maximum value of the repair is $0. By contrast, the duct leakage measurement at the home on Anson St. is an extreme outlier. Because a duct had broken loose from the return plenum, the leakage was drastic and not representative of the sample. The duct has since been repaired and is within the limits one would expect from a typical contractor.

Since, duct blaster testing was not performed on the Museum House, a stand in value of 20% leakage was used for the estimates based on RESNET protocol. A 20% duct leakage is not the worst possible result, but it is considered the maximum allowable leakage by current building codes.

Maximum Value: Duct Leakage

The graph below shows the present value of duct leakage repairs, or the maximum amount the property owners in this case study could spend on reducing their duct leakage to 4% or less based on square footage service by the HVAC system. These figures assume the cost will be amortized over the life of a 30-year mortgage.



Again, the figures for Anson St. represent an outlier. The graph shows the impact and importance of this building feature. The Anson St. homeowner could spend up to $12,021 on this repair and still break even. Fortunately, the repair will likely cost less than $1,000.

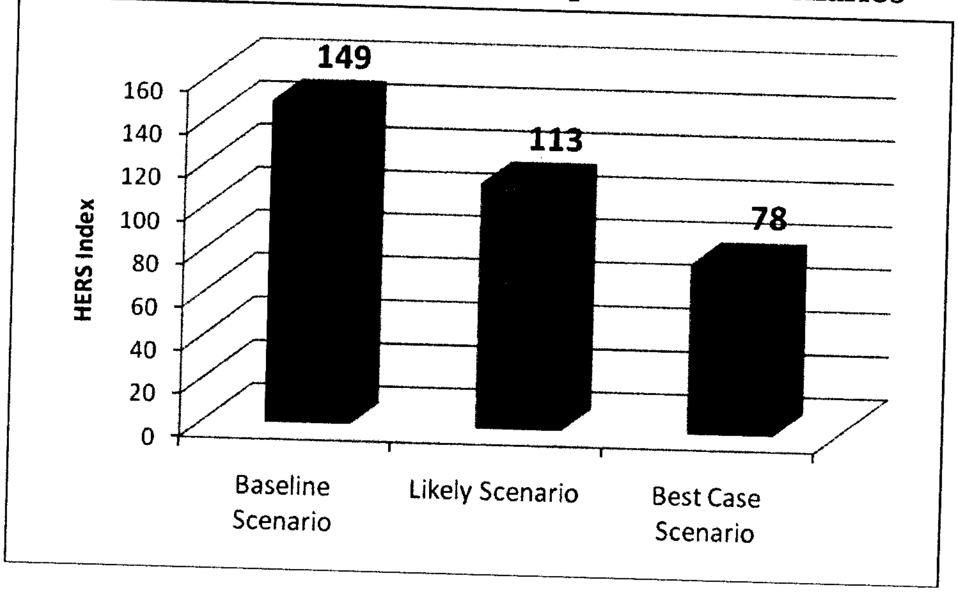
The figures for Tradd St. (2) and the Museum House are also not representative of the sample. The leakage rates at Tradd St. (2) are low enough to indicate that the sample is an outlier in the data set. Since duct blaster testing could not be performed on the Museum House, the savings figures are based on the standard RESNET protocol.

The remaining homes in the study indicate that the maximum value of the repair is less than the estimated cost of improvement. This indicates the repair would return a positive cash flow over the life of a 30-year mortgage and would be an advisable repair.

Improvement Scenarios

For each building, a "likely" and "best case" scenario of the building profile was created to model for possible future improvements. The "likely" case included the improvements that a typical property owner would probably undertake that are relatively simple and inexpensive to complete. The "best case" scenario included all of the improvements that provided the most energy savings regardless of their cost or feasibility. The three graphs below use averages from each home in the case study to show the effect these improvements could have on the overall ratings of the buildings.

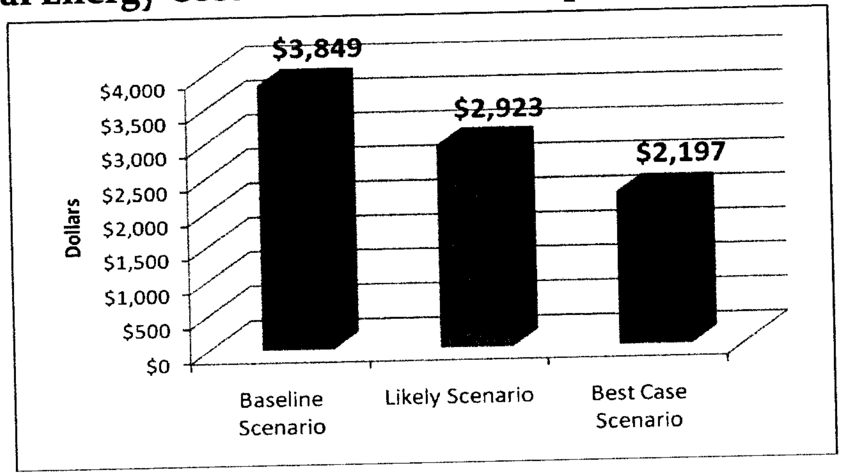
Home Energy Rating System Improvement Scenarios



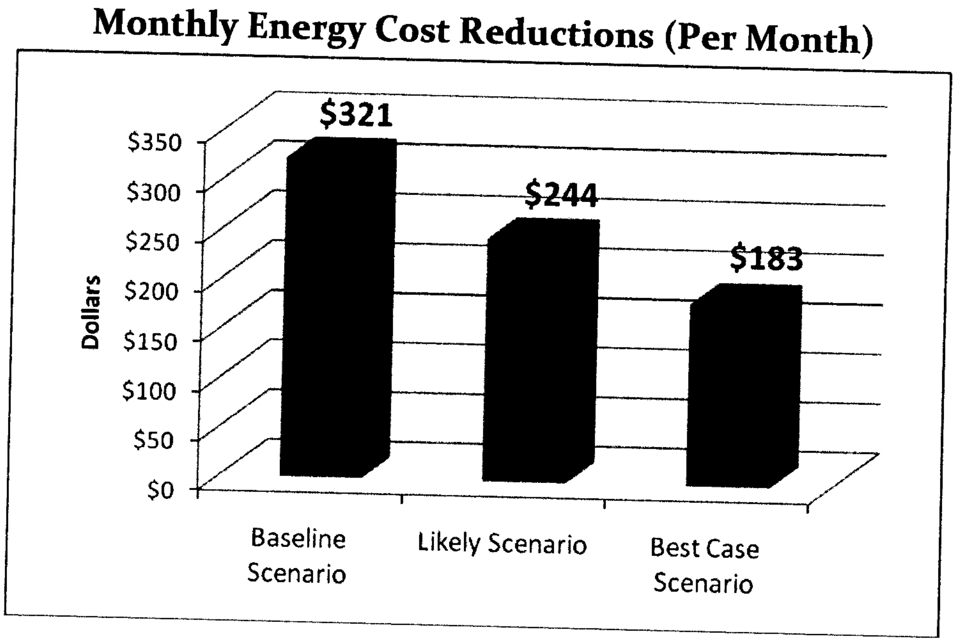
The graph above depicts the average baseline HERS rating for each of the homes in the case study. Each building was then analyzed based on the "likely" improvement scenario and the "best case" improvement scenario. The likely improvement scenario, on average, reduces the HERS rating to 113. These results indicate a 36% average increase in efficiency. Each of the improvements within this scenario produce a positive return on investment and have the capability of dramatically improving energy efficiency.

The best case scenario, on average, has the potential to reduce the HERS rating to levels below the requirement for the Energy Star green building program. On average, these repairs reduce the HERS Index to 78, which is 22% more efficient than the standard new American home and up to 71% more efficient than the baseline. Each of the improvements in this scenario fit within the confines of the *Secretary of the Interior's Standards for Rehabilitation*. Though the improvements do not offer a positive return on investment due to the high cost of implementation, the data suggests that historic homes are capable of surpassing the energy efficiency levels of newly built homes.

Annual Energy Cost Reductions for Improvement Scenarios



The "Annual Energy Cost Reductions" graph above depicts the average, relative energy savings from the three improvement scenarios. The average annual energy cost for the homes in the study is $3,849. On average, the likely scenario has the potential to reduce annual energy costs to $2,923. The best case scenario can reduce annual energy costs to $2,197. This represents a $1,652 annual energy savings.



The "Monthly Energy Cost Reductions" graph depicts the average monthly energy savings from the three improvement scenarios. On average, the likely scenario has the potential to reduce energy costs by $77 per month. The best case scenario can reduce monthly energy costs by $138.

Summary

All the recommendations in this report have been based both on established preservation guidelines and the economic considerations of any repairs. If a repair could not produce a positive return on investment, it was not included in the list of recommendations. Second, the recommendations stayed within the confines of the *Secretary of the Interior's Standards for Rehabilitation*. If a repair did not follow these standards, it was not included as a recommended improvement in this report.

Surprisingly, most of the economic considerations and arguments for improving the building envelope reinforce the preservation-minded approach. A repair involving replacement windows represents a good example of this finding. The research in this study found that window replacement was unadvisable from a financial perspective. The high up-front costs of wholesale window replacement rarely realize a positive cash flow over the life of a typical 30-year mortgage. The argument for window replacement may stem more from product advertising than from legitimate building science and cost benefit analyses.

Discussion

Envelope Leakage

Reducing envelope leakage should be the primary focus when dealing with energy efficiency. The study set fell generally within the anticipated leakage rates of historic buildings with one unusual finding: The Tradd Street (2) Residence had exceptionally low envelope leakage, testing at 42% air leakage to the outside of the building. This figure is quite low considering no extraordinary measures have been taken to retrofit the house or seal it to an exceptional degree.

This finding suggests that historic buildings are and can be capable of reaching envelope leakage levels competitive with modern construction by focusing on the air sealing details. Further, Tradd Street (2) also has no reported moisture issues. This indicates that low levels of envelope leakage commensurate with new construction are achievable in historic buildings without corresponding moisture issues that are typically feared when a building is sealed tightly.

Strategic improvements can be made to levels of envelope leakage by identifying and sealing leakage pathways through the ceiling and floors first. These areas are easily accessed and are appropriate repairs from a preservation perspective. Air sealing wall systems should focus on identifying and sealing pathways on the interior of the house. Leakage pathways in wall systems are often plumbing or electrical penetrations as opposed to windows and doors. As a result, many pathways can be repaired through the judicial application of caulk, spray foam, or weather-stripping. Again, this study shows that window replacement is not necessary to achieve reduced levels of envelope leakage and energy consumption.

Duct Leakage

Reducing duct leakage is perhaps the most preservation-friendly aspect of energy efficiency retrofitting for historic homes. Duct systems can be sealed and insulated without affecting the historic fabric of a building and this improvement makes a significant impact on the energy consumption of the building overall. By reducing duct leakage to 4% or less, the building can more effectively use the conditioned air to heat and cool the livable space in the house and prevent the loss of conditioned air to the outside of the house. Where possible, duct systems should be located within the conditioned area of the building to ensure that even if leakage occurs, it is contributing to the heating or cooling of the space.

Duct blaster testing on the Anson Street house reported egregiously high levels of leakage attributed to a detached return duct. Fortunately, the process of duct blaster testing revealed the problem and the homeowner was able to have the system easily repaired so that it could function properly. This provides an argument for performing blower door and duct blaster testing on historic buildings at regular intervals to identify and repair issues. Furthermore, pressure testing can offer a method for homeowners to guarantee quality workmanship from a contractor.

In contrast to Anson Street, the Tradd Street (2) had exceptionally low levels of duct leakage. This finding depicts the energy saving potential of quality HVAC installation and workmanship. This level of quality and attention to detail should be expected by every homeowner, and pressure testing offers the most convenient process for quality control.

Windows

Windows are a hot topic in historic preservation, especially with the increase in concern for energy efficiency in recent years. The data in this study suggests that single-glazed wood windows should not be replaced based on expected energy savings alone. According to the cost estimates and modeled energy savings, replacement windows will not return a positive cost benefit. Installing storm windows also provided a negative return on investment for all of the houses in the study. For this reason, both window replacement and storm windows were found to be economically impractical. The research further suggests that budgets for rehabilitation could be spent more appropriately on air sealing and insulation.

Heat gain through existing windows can also be mitigated at a relatively low cost. Installing blinds can create a valuable decrease in energy consumption, especially in a hot, humid climate such as Charleston. Curtains and other window treatments also provide much of the same effect as blinds, but may be more expensive.

Leaky historic windows can be rehabilitated to reduce envelope leakage. Rehabilitating windows with air sealing measures like weather-stripping and gaskets can reduce the leakage through the window. The installation of appropriate flashing around a window is another measure that can have a tremendous impact on the relative leakiness of a window. Flashing will prevent water damage and air leakage between the window assembly and the rough opening in the wall. These air sealing measures can be accomplished in a historically sensitive manner that has little impact on the historic fabric of the home.

Unfortunately, the actual amount of envelope leakage lost through windows and doors on historic structures has not been adequately studied. The majority of the research on this topic has been conducted on new buildings with contemporary windows and doors. This topic is discussed further in the “areas for further research” section of this report.

HVAC

Due to the high complexity of HVAC systems across different buildings, it is very difficult to recommend a specific type of system. Of course, when a property owner chooses a new system, they should choose the most efficient system they can afford, but the cost effectiveness of this choice cannot be determined except on a specific, case-by-case basis. This is not an area where trends are particularly helpful and, therefore, it has not been generalized in the study results.

In an effort to guarantee the purchase and installation of the most efficient heating and cooling system, homeowners should commission a Home Energy Rating and improvement analysis from the growing green collar industry of Certified Home Energy Raters. Raters can develop an energy model to accurately depict home energy use and work with the homeowner to determine which HVAC system is most appropriate for a household budget.

Water Heating

In every case, employing a solar heating unit *with the assistance of economic incentives* provided by the government returned a positive investment over the life of the unit. "Demand-Gas" refers to tankless water heating models that heat water instantly in response to demand instead of constantly heating in the event that the hot water is needed. Despite the fact that tankless water systems are one of the most efficient models to use, only one building, Tradd Street (2), demonstrated a positive return on investment over the life of the unit. All other types of upgraded water heating units were too costly to justify any energy cost savings that they provide.

Appliances and Lights

In all of the buildings studied, there was a negative return on investment for adding Energy Star-rated appliances to the house. While replacing already-functioning appliances for Energy Star may not make sound financial sense, upgrading with more efficient appliances at the end of their life is a logical choice. Lights, on the other hand, are an extremely easy and profitable option for energy retrofitting in a historic structure. In all of the buildings studied, replacing light bulbs with compact fluorescents provided a positive return on investment. In fact, the average net savings of completing this retrofit was $862 with a payback period of one year.

The Building's Lifecycle

There are two moments in a building's lifecycle when homeowners have the best opportunity to increase the energy efficiency of a home--when a homeowner decides to repaint the interior of a house and when a new HVAC system is required. At these times, much can be accomplished with air sealing and insulation details.

When a home's interior is repainted, homeowners or contractors can take advantage of a blower door test to identify the leakage pathways through the building shell. Before paint is applied, all forms of air sealing are possible, including caulking and spray foam. After air sealing, paint will hide any of the improvements made. Homeowners should take this opportunity to improve the building envelope through air sealing and the addition of insulation.

When installing a new HVAC system, a contractor will use the building's design characteristics to size a system appropriately. Factors like building orientation, envelope leakage and insulation levels all impact this process. All things being equal, a well-sealed and well-insulated building envelope is easier to heat and cool. Air sealing and insulating before systems are replaced allows for a potential size reduction of the HVAC system, which would save on the installation and operating costs.

If air sealing and insulation occurs after the installation of an HVAC system, the reduced heat gain may cause the HVAC system to short cycle. "Short-cycling" is a process by which the HVAC system will activate, cool a space rapidly, and turn off. Short-cycling is hard on equipment, and can be likened to driving in stop-and-go traffic. Short-cycling shortens the life span of mechanical equipment and increases operational costs. In many instances, short-cycling can inhibit an HVAC system's ability to remove moisture, causing comfort issues in the house.

Therefore, homeowners should take the opportunity to improve the building envelope at these moments in a building's lifecycle in an effort to increase efficiency, be more cost effective and reduce the building's environmental footprint.

Areas for Further Research

With any research there is always more that can be studied to better improve upon the subject. Over the course of this study, it was determined that further understanding of historic windows and their impact on energy use is an area that needs additional independent research. The exact impact of air leakage from historic wood windows on the overall energy use in a building is unknown. This subject could be much better understood from a simple leakage testing conducted exclusively on each window. If the window was tested before and after rehabilitation, the benefits of performing the repair could be better understood. In this way, the cost of rehabilitating a historic window and its subsequent energy savings could be compared to determine whether the action was cost effective.

Additional study is also advisable on the topic of moisture dynamics in historic buildings. Software modeling programs are available that can be used to calculate the coupled heat and moisture transfer in building components. This type of analysis can be used to predict moisture transfer to avoid the common pitfalls in the rehabilitation of a historic property.

Energy efficiency in historic structures has just begun to be seriously studied. This project has only scratched the surface of understanding how energy is used and lost in historic buildings in a warm, humid climate such as Charleston. An abundance of research can certainly still be completed on this topic to reinforce the trends that have already been presented in this study. Because the data set of five buildings is still relatively small, it would be very constructive to continue adding more local historic buildings for testing in order to increase the sample set and better understand the performance of diverse historic buildings representing different construction periods and material types. Increasingly, owners of historic properties have been requesting energy audits and it is expected that interested parties will come forward even more frequently in the future.

With an improved data set, guidelines could be produced that are similar to those found in Great Britain. This information would better guide property owners and contractors alike to more effectively retrofit historic structures by both protecting their materials and improving their impact on energy use in the community. As energy costs continue to rise and sustainability issues are more widely discussed, the importance of retrofitting our existing housing stock will become a central theme in our quest for improved energy efficiency.

Suggested Reading List

Giuliano, Meg. "Energy *Efficiency, Renewable Energy and Historic Preservation: A Guide for Historic District Commissions."*Clean Air-Cool Planet. (2009). http://www.cleanair-coolplanet.org/for_communities/HDCGuide.pdf

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Krigger, John & Chris Dorsi. *Homeowner's Guide to Building Performance.* Saturn Resource Management, 2008. http://srmi.biz/Bookstore.Homeowners.Homeowners_Guide_to_Building_Perfor.htm

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Lstiburek, Joseph, *Builder's Guide to Hot-Humid Climates.* Building Science Press, 2005. http://www.eeba.org/bookstore/prod-Builder_s_Guide_to_Hot_Humid_Climates-1.aspx

National Trust for Historic Preservation. Articles and case studies on historic preservation and sustainability. http://www.preservationnation.org/issues/sustainability/

Southface Energy Institute. *Fact Sheets* and *Technical Bulletins.* http://www.southface.org/web/resources&services/publications/factsheets/sf_factsheet-menu.htm

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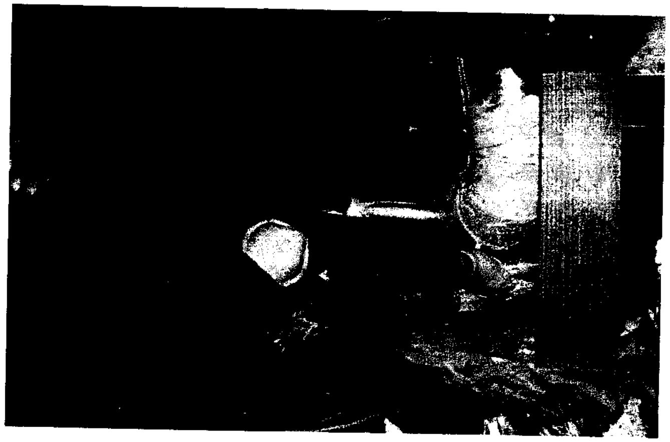
How do you fix it?



Total Comfort's technicians are not just state and utility certified for testing for leaks in your ducts and home, they also have vast experience in hunting down those leaks and stopping them.

To seal the holes in your ducts, Total Comfort will first make sure that the ducts are properly supported and connected at every joint. Then we will apply an air-tight fibered mastic to every joint that we can reach. This will permantly seal the ducts so that the work will never have to be done again.

To seal out the drafts from your home, Total Comfort will start by sealing around all of the penetrations practical in your floor and ceiling. Then, if needed, we will search for leaks through your walls and seal them as well.

When Total Comfort's crews think they have sealed your ducts and house properly, we will do another Duct Blaster/Blower Door Test to make sure. That way you can rest assured that the work has been done properly.

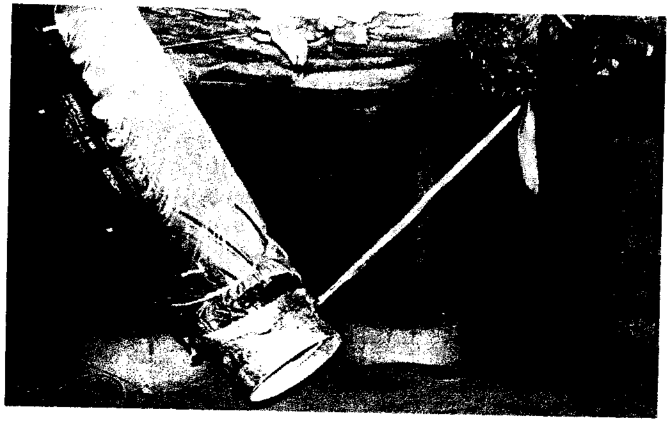
Can leaks make you sick?

Yes they can! Leaks in your ductwork can blow allergens and dangerous particles into your home. Common contaminants include dust; insects; mold; mildew; spores; animal residue; radon; and hazardous combustion gasses from your furnace, water heater, wood stove, or even your car.

Leaks in your home can cause negative indoor air pressues which often lead to backdrafting in fireplaces, wood stoves, furnaces, and hot water heaters. They can also force the air from under your house to enter; this air often brings in moisture, mold, and mildew with it.

New homes have problems too

This duct under an $800,000 home built in 1999 is typical of what we often find under newer homes. This disconnected duct not only led to outrageous heat bills, but also allowed insects and dust an easy path into the home. New homes can also have serious leaks in their envelopes leading to high heat bills, lack of comfort, and health risks.



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How leaky is your home?

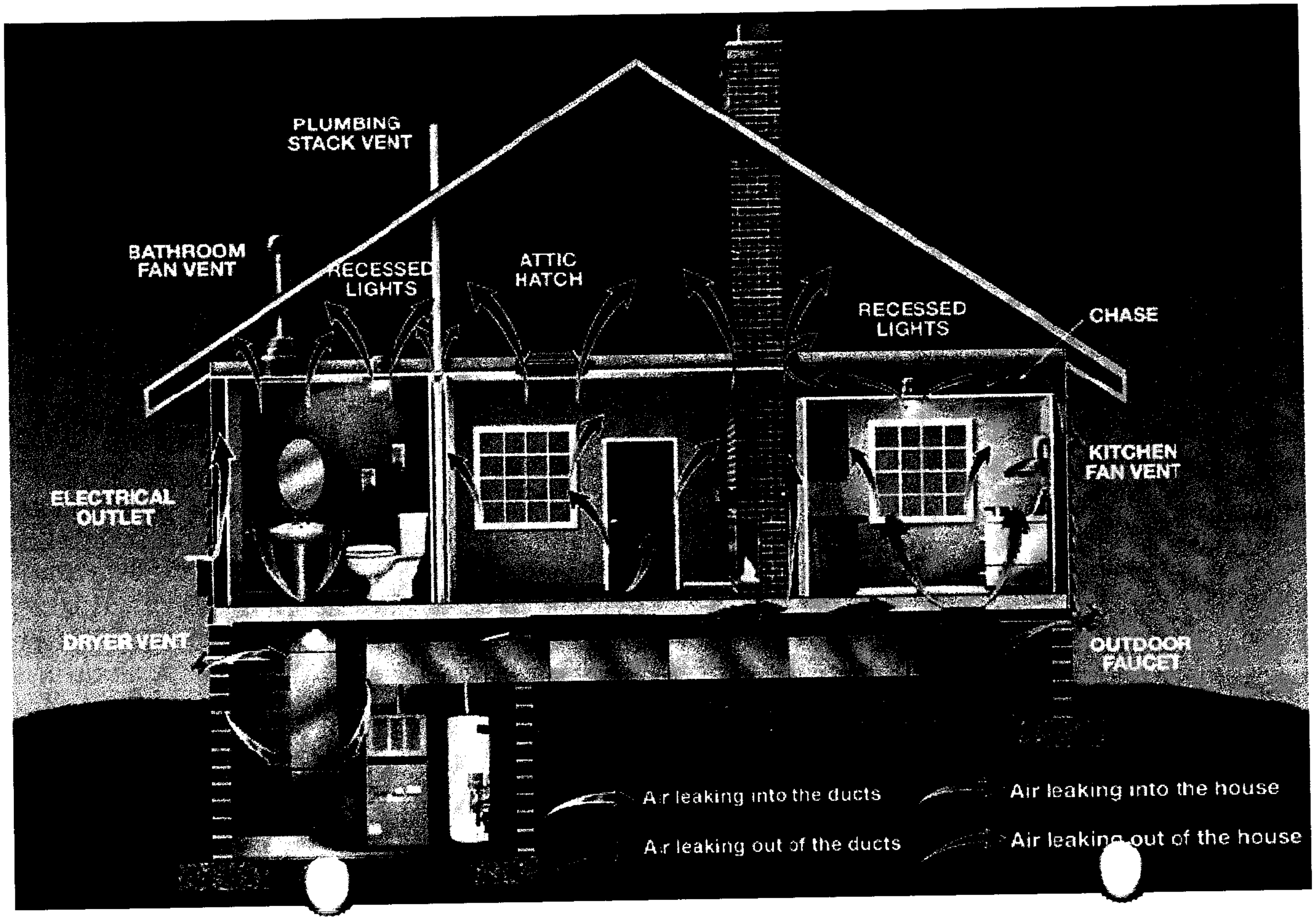
The two worst energy wasters in your home are probably the ones you have never thought of. Most home's ductwork is so leaky that 25-45% of all the heat produced by the funace never reaches the inside of the home. Likewise, most homes have so many small holes in the floor, walls, and ceiling that 35% of all the heat that does reach the inside of the house escapes right through them!

So the question is, how leaky is your home? Otherwise put, how much money are you wasting every day on heating your attic or crawlspace? How much more comfortable would your home be if these leaks were stopped?

The only way to tell is with a specialized, two-part, test called a Duct Blaster/Blower Door Test. This test uses a set of calibrated high-pressure fans to blow air into your ducts and home and a set of pressure gauges to measure how fast that air leaks out of your home and heating ducts.

Where do ducts leak? Ducts leak at every joint and your home might have dozens of joints. Originally many of these joints were sealed with duct tape, but tape doesn't last. After just a few years it loosens and allows your heated air to leak into your crawlspace or attic.

Where do homes leak? For years the conventional wisdom was that most air leaks (drafts) come from around windows and doors. Testing, however, has proven that the worst leaks are usually around heat registers, plumbing, wires, fireplaces, and anywhere else you have holes in the floors and ceilings.



Are Your Ducts All in a Row?
Duct Efficiency Testing and Analysis for 150 New Homes in Northern California

Fred Coito and Geof Syphers, XENERGY, Oakland, CA
Alex Lekov, LBNL, Berkeley, CA
Valerie Richardson, PG&E, San Francisco, CA

ABSTRACT

An impact evaluation was recently completed for PG&E's residential new construction program. Key measures in this program included high efficiency central air conditioners and enhanced duct installations. To evaluate this program, over 300 comprehensive building surveys were conducted, and a calibrated engineering analysis was developed to compare as-built homes with reference case homes.

To evaluate the duct component of the program, "duct blaster" tests were conducted on a subset of 158 homes to establish duct system performance with respect to leakage. Information about the duct system for each home (including physical dimensions, location, insulation levels, and leakage) was then run through a distribution system efficiency model. The model, developed by LBNL, is based on the draft ASHRAE 152P Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems 1997. The distribution system efficiency estimates were combined with Micropas simulation results and engineering estimates of energy consumption for non-HVAC end uses to provide "whole building" usage estimates. Participant and nonparticipant energy usage could then be calibrated to customer bills and compared to establish program savings.

This paper focuses on the duct system analysis portion of the evaluation project. The duct testing and analysis are described. Duct leakage test results are then presented along with a comparison of test results for program participants and a matched group of nonparticipants. Finally, calculated distribution system efficiencies are compared against default HVAC Duct Efficiency Factors that are assumed for California Title 24 compliance modeling.

This project provides a relatively large-scale look at duct system efficiency in new homes. In addition, the modeling approach provides a method for integrating duct test data into a Micropas simulation analysis.

Introduction

Forced air distribution systems can have a significant impact on the energy consumed in residences. A number of utility programs exist to improve duct efficiencies through duct testing, repair, and contractor training. The primary goal of these programs is to make tight duct construction commonplace through educating contractors about typical problems such as inadequate joint sealing, improper use of adhesive connections, and a lack of sealing at the blower housing.

Duct sealing and insulation programs have had variable impacts on air distribution system efficiencies. Air distribution system leakage reduction from duct testing and repair ranges from 22% improvement (Karins et al, 1997) to 70% improvement (Palmiter and Olsen, 1994) with values

60% (Bissei and Davis 1995; Cummings et al 1990, Downey 1994; Jump and Modera
ı91; Strunk, 1996.)

uct losses can account for 30-40% of residential HVAC energy consumption
Tooley 1989; Lambert & Robison 1989; Davis 1991; Modera et al 1992; Palmiter &
; Stunk et al 1996; Walker et al 1996), PG&E has encouraged the installation of
ystems by including a duct component in their residential new construction program (the
s program). The program also provided incentives for the installation of high efficiency
itioners, gas cooking, and gas clothes dryer stubs.

impact evaluation of PG&E's residential new construction program, savings estimates
for the key program measures. The approach used for this evaluation was a structured
s referred to as an SAE (statistically adjusted engineering method). In this method,
timates of energy use are calibrated to customer bills using a cross-sectional time series
lysis. Estimates of savings for each key program measure are developed by comparing
ineering results for participants against results for nonparticipants. On-site surveys on
s, were conducted to support the analysis. Duct tests were conducted on a subset of 158
e additional data on the efficiency of the air distribution systems.

se enhanced duct installation was a key program measure, a cost-effective method was
entify differences in duct efficiencies between participants and nonparticipants. The
en for the evaluation was the use of duct blaster testing to determine duct leakage, and
ı of duct leakage measurements into distribution system efficiency estimates using
sed on the draft ASHRAE 152P Method of Test for Determining the Design and Seasonal
ff f Residential Thermal Distribution Systems.

primary purpose of this paper is to report results of the duct testing and analysis portions of
this ı ely large-scale impact evaluation.

Background

A number of methods exist for testing air distribution system efficiencies. There are at least three quantitative tests appropriate for large-scale projects (Proctor et al 1993): blower door subtraction, blower door and flow hood combination, and duct blaster. In the blower door subtraction method, the house is first pressurized to 50 Pa with a blower door to obtain the total leakage of the home. Next, a second blower door flow reading at 50 Pa is taken with the duct registers and return grill sealed. The difference between the two flow readings is a measure of the leakage through the duct system. With the blower door and flow hood combination method, the registers are sealed and a flow hood is attached to the return grill. The house is pressurized to 50 Pa with a blower door and the flow through the hood is used to approximate the duct leakage. With the duct blaster method, the registers are sealed, a variable speed fan is attached to the supply fan compartment or the return grill, and the air distribution system is pressurized to 25 Pa. The air flow into the ductwork is a measure of the leakage.

For this study, the duct blaster method was chosen for its simplicity and relative ease of use. No attempt was made to compare the merits of the various duct leakage tests. This issue is addressed in detail in the existing literature (i.e., Proctor et al 1993). The duct blaster test was chosen because the equipment is relatively compact, making for easy transportation, and because duct blaster tests do not require multiple equipment configurations like the blower door subtraction method and the blower door flow hood combination test. This simplicity keeps the test time short, and less obtrusive to the surveyed homeowner, a plus for large studies.

Equipment

The equipment used for this study is the Minneapolis Duct Blaster Systems' Series B unit with DG-3 digital gauges. A manual controller on the duct blaster is used to adjust the fan speed to obtain the reference pressure. The gauge samples the fan speed and duct pressure to calculate a volume air flow into the duct system, based on manufacturer calibration. The digital gauges have rated accuracy of ±1%, and were chosen to reduce the possibility of reading error compared with analog gauges.

The duct blaster consists of the following major components: a fan, a digital pressure measurement gauge, a fan speed controller and a flexible extension duct. The duct blaster system chosen for the study is manufactured by the Energy Conservatory in Minneapolis, and meets the flow calibration specifications of the standards. It is capable of moving up to 1,350 CFM against 50 Pa of back pressure and has a flow accuracy of +/-3%.

Duct Blaster Technique

The duct blaster method used in this study involves pressurizing the full air distribution system to a reference pressure and measuring the air flow needed to maintain that pressure. This air flow is the total leakage from the system, and is representative of the operating leakage when the reference pressure is similar to the average operating pressure.

Duct leakage is measured by first connecting the duct blaster system to the ducts at either a central return grill or at the air handler access door. After sealing off all the supply and return registers, and combustion or ventilation air inlets, the duct blaster is used to pressurize the entire duct system to a standard testing pressure. The duct pressure at which the test is conducted is representative of the average actual duct operating pressure and is typically predetermined by the program test protocol (e.g., 25 Pa or 50 Pa). In this case, a reference pressure of 25 Pa was chosen. The air flow needed to maintain the reference pressure is generated by a calibrated variable-speed fan. The pressure across the fan required to maintain the reference pressure in the duct system is measured, and converted to air flow in cfm based on calibration tests performed by the manufacturer of the duct blaster equipment. The air flow is the total duct leakage at the reference pressure.

Duct Leakage Disaggregation

The total duct leakage value obtained from the duct blaster test consists of leakage to outside plus leakage to inside. Since air lost to the interior helps condition the space, it does not affect the energy consumption of the HVAC system. For this reason, it is necessary to separate out the losses to the unconditioned spaces and outside from the losses to the conditioned spaces. This disaggregation, along with the calculation of the overall thermal performance of the distribution system, is accomplished with a spreadsheet application from Lawrence Berkeley National Laboratory (LBNL) based on calculation algorithms from ASHRAE Standard 152P.

Duct leakage to the outside was calculated using measured total leakage data and assumed disaggregation fractions. Based on the homes in the study, is was assumed that 75% of the air loss was from the supply ducts and 25% of the air loss was attributable to the return ducts. In addition, 15% of the total duct leakage was assumed to be conditioned spaces, and did not contribute to losses.

Duct Efficiency

In order to combine duct test results with Micropas simulation results, distribution system efficiency estimates were required for the project. From the disaggregated duct leakage values, it was possible to utilize some of the algorithms developed for Standard 152P to estimate the efficiency of the air distribution system. The model was developed to better determine actual duct efficiencies utilizing site-specific data.

In addition to the duct leakage values, the procedure requires information about the supply and the return duct location, the size of the home, the ambient conditions, duct surface area, duct insulation level, heating and cooling system capacities and fan flow. Table 1 summarizes the input parameters required for the model and the source of these inputs. Some data were collected during the on-site surveys while others were calculated based on surveyed data or assumed from standard practice and ASHRAE protocols. In addition, standard CEC climate data were utilized for weather-related inputs. The following table lists each input and its source.

Table 1. Duct Efficiency Model Input Parameters

Parameter	Surveyed	Calculated or Lookup[1]	Assumed
Conditioned Floor Area, and House Volume	✓		
Supply & Return Duct Surface Areas		✓	
Fraction of Ducts in Conditioned Space			✓
Supply & Return Duct R-values	✓		
Thermostat Setpoint, Heating & Cooling	✓		
Heating & Cooling Design Temperatures		✓	
Design Wetbulb Temperature		✓	
Indoor Wetbulb Temperature		✓	
Attic Solar Gain Reduction [y/n]	✓		
Equipment Heating & Cooling Capacity	✓		
Heating & Cooling Fan Flow		✓	
Heating & Cooling Supply & Return Duct Leakages	✓		
Duct Thermal Mass Correction	✓		
Equipment Efficiency Correction	✓		
Is The Attic Vented?	✓		
Is There A Thermostatic Expansion Valve?		✓	
Is Heating System A Heat Pump?	✓		

[1] Calculated values are based on survey data or lookup part numbers in manufacturer's literature.

Parameters that were not directly recorded during the on-site surveys but were calculated as part of the analysis were the duct surface area and fan flow. Equations 1 and 2 show how these parameters are calculated using the Standard 152P-based model. The results provide seasonal thermal distribution system efficiencies for both heating and cooling systems that are used later in computing energy consumption.

$$Cooling\ Capacity \times 340\ cfm/ton = Supply\ Fan\ Flow \qquad \text{Eqn. 1}$$

$$Supply\ Duct\ Surface\ Area = 0.27 \times Floor\ Area \qquad \text{Eqn. 2a}$$

$$Return\ Duct\ Surface\ Area = K_r \times Floor\ Area \qquad \text{Eqn. 2b}$$

where $K_r = 0.05$ if there is one return register and 0.10 if there are two

The overall design and seasonal heating and cooling thermal distribution system efficiency calculations are not complicated, but involve a rather large number of steps, therefore, the reader is referred to the source (ASHRAE Standard 152P) for details.

Energy Consumption Calculation

Once the air distribution system delivery efficiencies were known and the loads calculated with Micropas, it was easy to develop estimates for the HVAC energy consumption. Using the system efficiencies obtained in the on-site surveys, energy usage for cooling and heating was calculated as follows:

$$Energy = \frac{load}{systeff \times ducteff} \times conv \qquad \text{Eqn. 3}$$

where:

load = Micropas load estimate in kBtus for cooling or heating
systeff = system efficiency for cooling (SEER) or heating (AFUE)
ducteff = duct efficiency (fraction between 0.0 and 1.0)
conv = conversion factor to translate from kBtu to kWh or therms

Energy Savings Calculations

For the evaluation, estimates of energy savings above the Title 24 reference were determined by subtracting "as-built" energy usage from reference energy usage. Using Equation 3 above, as-built energy usage reflects the as-built loads from Micropas, the actual system efficiencies (SEER and AFUE), and the calculated duct efficiencies. Reference energy use reflects the Micropas reference loads, standard system efficiencies (10 SEER and 0.78 AFUE), and reference duct efficiencies (based on the nonparticipant average for cooling and heating).

Results

Ultimately, the goal of this study was to produce energy savings estimates for the various measures rebated under the Comfort Home Program. Along the way toward this goal, a number of interesting results relating to duct leakage testing were found.

As shown in Figure 1, the range of duct leakage is roughly the same for both program participants and nonparticipants. Data for this chart were sorted into lists of increasing duct leakage. Through sorting equal numbers of participant and nonparticipant observations in this way, it is possible to see trends in data where the ranges overlap. So while the ranges of duct leakage are the same for program participants and nonparticipants, the figure shows that the average duct leakage is significantly lower for participants. The most likely explanation for this behavior is that most nonparticipant contractors built more leaky duct systems, but a few did a good job even without incentives, and while most participant contractors built better-sealed duct systems, a few built leaky ones. It is also possible that the leakage in some duct systems may have increased over time.

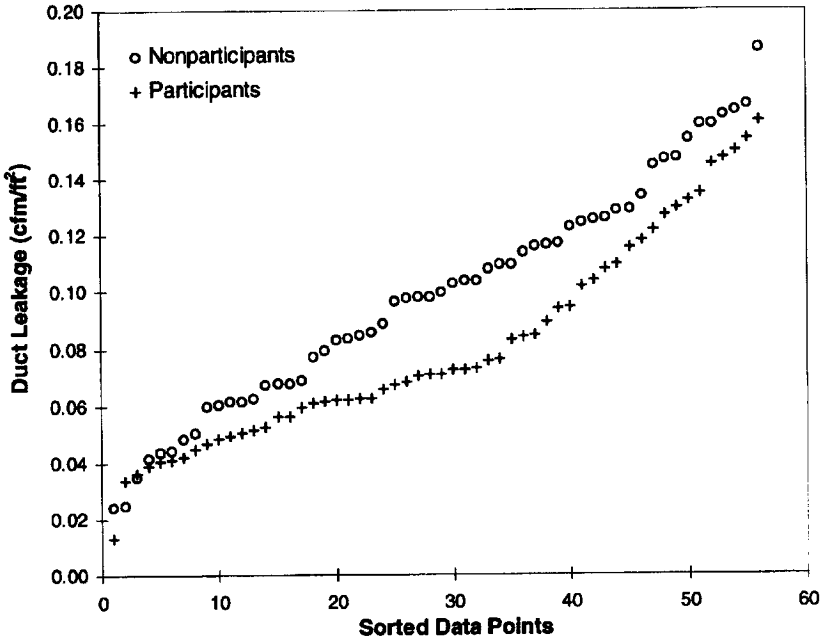


Figure 1. Measured Duct Leakage Normalized to Home Floor Area

The calculated heating and cooling seasonal duct efficiencies are presented Figure 2 and Figure 3. The results clearly show that the CEC default duct efficiency assumptions for 1-story homes are at the very highest end of measured results, while the CEC defaults for 2-story homes are so high that they are represented by only two homes. These findings support the decision to adjust the reference duct efficiency to match the average measured nonparticipant efficiency.

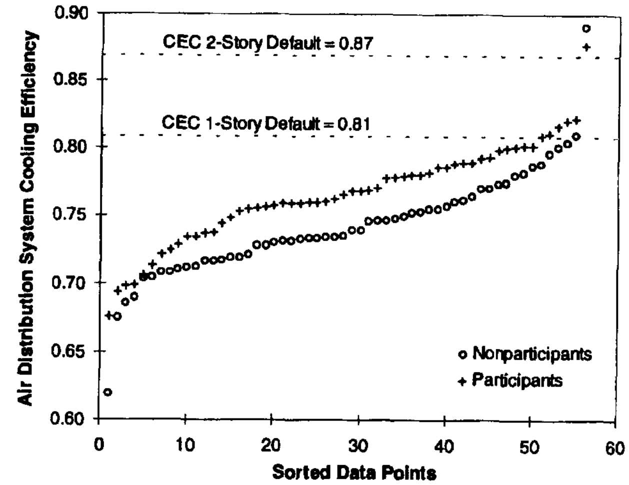


Figure 2. Measured Air Distribution System Cooling Efficiency

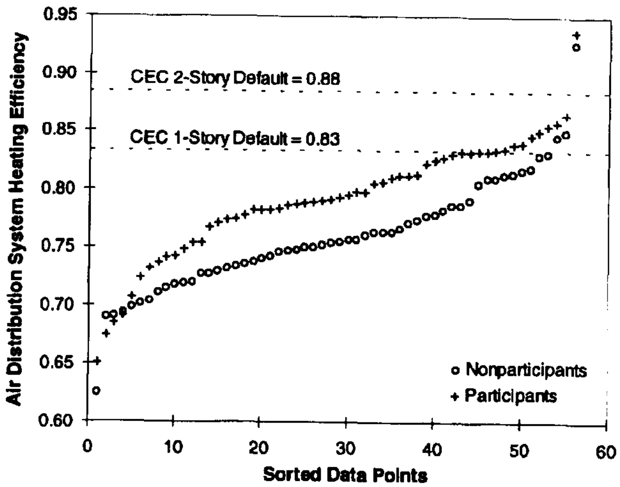


Figure 3. Measured Air Distribution System Heating Efficiency

It appears that the default duct efficiencies applied to external load calculations in Micropas (and also published in the CEC compliance manual) tend to overstate actual duct efficiencies. The effect of this overstatement may be that both participant and nonparticipant "as-built" duct systems show lower efficiencies than the default Micropas efficiencies. This effect could lower gross program savings relative to an artificially efficient reference case (although net impacts that rely on differences between participants and nonparticipants are unaffected). To avoid this problem, the reference duct efficiencies were adjusted to reflect more realistic values using the average nonparticipant duct efficiencies for heating and cooling.

Duct Efficiency Parameters

Average duct leakage and duct efficiency estimates for all study homes are presented in Table 2. As the table indicates, the participants performed better than the nonparticipants both in terms of duct leakage (lower) and duct efficiency (higher). Duct efficiency differences between participants and nonparticipants were statistically significant at the 99% confidence level. As expected, the average duct efficiencies were lower than the efficiencies used in the compliance model.

Table 2. Duct Efficiency Parameters

	Participants	Nonparticipants	Average	Compliance Value
Duct leakage, cfm	144	187		
Duct leakage, cfm/sf	0.081	0.100		
Cooling efficiency	0.768	0.741	0.759	0.860
Heating efficiency	0.794	0.756	0.781	0.873

Conclusions

The duct blaster technique was effective for obtaining sufficiently accurate leakage data to satisfy the California utility program review standards. Beyond this, the duct blaster is easy to operate, and fairly transportable. The duct analysis model, which uses algorithms from ASHRAE Standard 152P, provides a useful method for calculating the seasonal and design heating and cooling air distribution efficiencies from survey data. The spreadsheet tool developed by Iain Walker of LBNL to implement the standard saves considerable time—especially when evaluating data from a large number of sites.

A comparison of participant and nonparticipant duct leakage estimates shows a reduction of 19% for the PG&E program participant homes (0.081 cfm/sf versus 0.100 cfm/sf). This reduction in duct leakage (and subsequent increase in distribution efficiency) was much lower than initially predicted. Indeed, the gross savings developed during the evaluation were only about half of the initial program estimates.

The lower savings estimates do not appear to be driven by nonperformance of participating homes. Rather, the nonparticipant homes appear to have increased in efficiency over homes built in past years. Nonparticipant leakage estimates of 187 cfm (see Table 2) are much lower than results reported in earlier studies which showed average duct leakage to exceed 250 cfm in some cases (Jump 1996, Modera 1993).

The improved distribution system performance in nonparticipant homes is probably the result of several factors. First, program spillover may be at work as several nonparticipant builders claimed their past association with the PG&E program contributed to their use of enhanced duct installation practices. Second, increased oversight by building inspectors may be contributing to improved construction practices. Finally, increased awareness of better duct installation practices has resulted from the work of organizations such as LBNL and the Florida Solar Energy Center.

Finally, the duct efficiency calculations from this study show that the CEC default assumptions for heating and cooling duct efficiencies may be significantly higher than the duct efficiencies in typical new homes.

Acknowledgments

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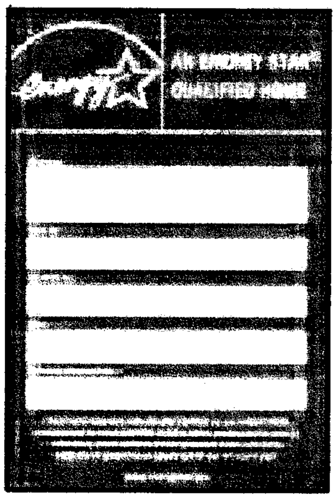
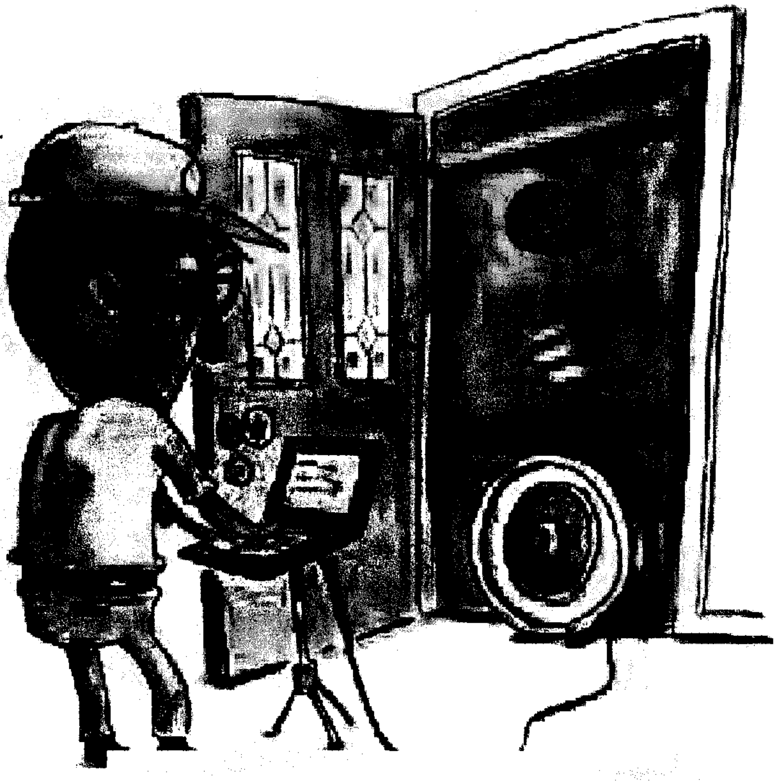


HOW DO I KNOW IF THE HOUSE I WANT TO BUY WILL BE ENERGY-EFFICIENT?

- First, ask the seller for copies of the monthly utility bills as indicators how efficiently the home operates. Low bills may indicate energy effici however, they may merely reflect the owners' infrequent use of heati and cooling.
- If you are seriously considering buying the house, you should also consider having a blower door test *(see illustration on page-2)* and a duct blaster test performed. These tests, which cost around $250, measure house and duct system air leakage and identify the places that need repairs to reduce the leakage. Once these tests are completed it is possible to have a Home Energy Rating System (HERS) analysis performed; which can help you if you want to apply for an Energy Efficiency Mortgage (EEM, discussed in more detail later).

COOPERATIVE EXTENSION

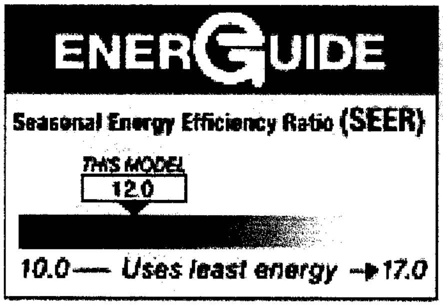
BLOWER DOOR TEST
A blower door test measures house and duct system air leakage. This test enables you to have a Home Energy Rating System (HERS) analysis performed which can help if you want to apply for an Energy Efficiency Mortgage (EEM).

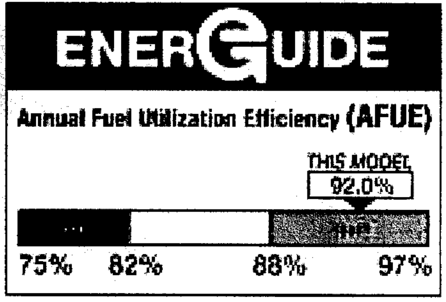


- Heating and cooling (HVAC) typically consume forty-five percent of the energy that a house uses. You should gather information on the furnace and air conditioner for any house that you may purchase. Be sure to have the following questions about the heating and cooling systems answered:

1. What are the HVAC efficiencies?
For air conditioning you are interested in the seasonal energy efficiency rating (SEER) and for gas furnaces you are interested in the Annual Fuel Utilization Ratio (AFUE).

2.How old are the systems?
If the equipment is 10-15 years old with a SEER of 8 or less, the time may be approaching to replace the system. You should consider this before making an offer for the house.





3. What is the condition of the systems?
You may need a professional, such as the energy rater mentioned earlier, to assist in determining the condition of the systems.

- Also consider the age and condition of the home's appliances. For example, a refrigerator that is over ten years old is probably not energy-efficient and will need to be replaced. You should not pay a premium for a house with inefficient appliances that will need to be replaced.
- Inspect the insulation in the attic. Insulation coverage should be continuous and thick enough to cover all the studs. An energy rater can also help you assess this critical area.

UPGRADING INEFFICIENT HEATING AND COOLING EQUIPMENT

- If you plan to replace both the heating and cooling equipment, consider replacing them with an efficient Energy Star® unit with a Seasonal Energy Efficiency Ratio (SEER) of at least 14 and for heat pumps a Heating Seasonal Performance Factor (HSPF) of at least 8.2. A SEER of 14 is also recommended when you are only replacing the air conditioner and coil.
- Installing properly sized equipment is critical and can be estimated by running a model called ACCA/ANSI Manual J® or an equivalent model. Contractors frequently oversize the equipment. The Department of Energy now requires the contractor to perform documented sizing calculations based on Manual J® procedures. If you install an over-sized unit, it will never reach its rated efficiency, and humidity control will not work properly. Both initial and operating costs will be higher, and the unit will actually cool your home less effectively than a properly sized unit.
- If you choose a gas furnace, choose one with an AFUE greater than 90 percent with a variable speed fan. This type of unit improves filtration, decreases temperature swings, is quieter, and controls humidity better.
- It is crucial that you have new systems installed properly. Ideally, choose service technicians who are certified by North American Technician Excellence (NATE) to install and service heating and cooling systems. To find a contractor in your area that employs NATE-certified technicians, visit **www.natex.org**. A duct blaster test after equipment replacement and duct repair can confirm the duct leakage reductions.
- Install an Energy Star® programmable thermostat so that you can control energy use by scheduling appropriate temperatures for different times of the day. An Energy Star® programmable thermostat can save you $100 each year in energy costs; it will pay for itself within a year.

PAYING FOR AN ENERGY-EFFICIENT HOME OR EFFICIENCY UPGRADES WITH AN ENERGY EFFICIENCY MORTGAGE (EEM)

Obtaining an EEM allows you to finance the cost of energy efficiency improvements while reducing your monthly expenses for mortgage and utilities. EEM's are available through FNMA (Fannie Mae), Freddie Mac, HUD and FHA. **www.hud.gov**

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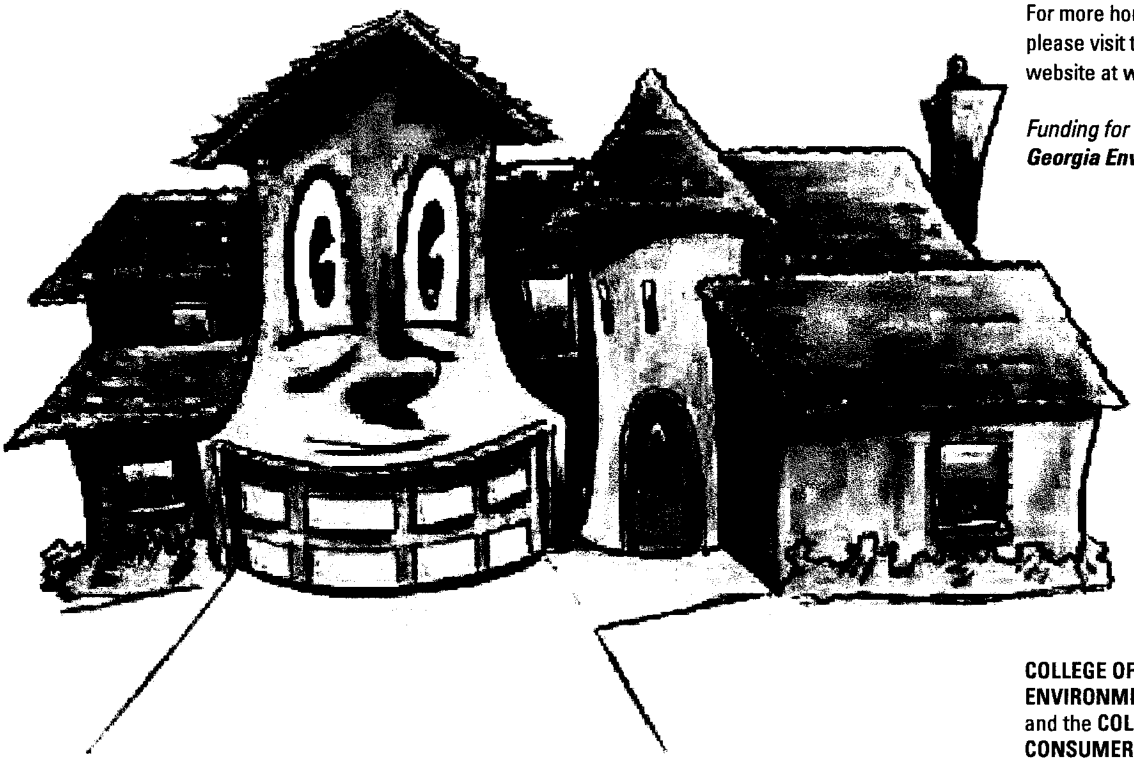

For more household energy savings information please visit the **UGA COOPERATIVE EXTENSION** website at **www.fcs.uga.edu/Housing**.

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Measuring residential duct efficiency with the short-term coheat test methodology

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Abstract

Assessing the thermal efficiency of a forced-air distribution system is difficult, in large part because of interactions between energy loss mechanisms and other building characteristics. This paper describes short-term coheating, a method of measuring the thermal efficiency of residential heating and cooling distribution systems in situ, and presents the results of a series of studies that utilized the short-term coheat methodology. Short-term coheat tests were conducted in 53 residential buildings including both site-built and manufactured housing. The magnitude of the distribution efficiency, defined as the ratio of the energy required to heat the building if there were no duct losses to the actual heating energy required, ranged from less than 50% for homes with disconnected ducts to more than 90% for well sealed and insulated systems. Duct retrofits were also performed at 20 of the test sites and, following the retrofits, on average, the homes required 16–17% less heating energy. These results show that residential distribution system losses can be responsible for substantial energy loss and that duct retrofits are a viable energy conservation strategy for homes with distribution systems located outside of the conditioned space.

Keywords: Heating system; Duct efficiency; Forced-air; Duct air leakage; Single-family homes; Manufactured homes; In-situ measurements

1. Introduction

Energy losses and gains through residential HVAC duct systems can have a profound influence on heating and cooling energy use. In heating mode, ducts located outside of the conditioned space, such as in attics and crawlspaces, can lose heating capacity by both conduction and air leakage. In cooling mode the ducts can lose cooling capacity by conduction and air leakage, and in addition, there can be more complex impacts on air conditioning because of possible increased latent loads on the coil due to return-side air leakage. Although there are recent attempts to promote the installation of residential HVAC ducts within the conditioned space, much of existing and new US housing stock still has fully or partially exterior ducts.

A series of studies in the late 1980s and early 1990s quantified energy losses due to ducts in unconditioned spaces. Robison and Lambert [1] estimated an average distribution efficiency loss of 12% in 20 Oregon homes. Parker [2] found that homes heated with electric furnaces used 21% more energy for heating than did homes heated with baseboards, when normalized by floor area. In this same study, Parker found that the homes with baseboards had 41% less infiltration, which also impacts energy use. Cummings et al. [3] found that 24 Florida homes had air-conditioning energy use reduced by 18% after duct repairs were made.

These studies initiated a serious research effort aimed at quantifying the effects of duct leakage on energy use and, more generally, the distribution efficiency of residential thermal distribution systems. Losses due to conduction across duct walls have been acknowledged for a long time. There has also been acknowledgment that leakage has the potential to be significant. In 1960, Carrier [4] stated that experience indicated that residential supply duct leakage averaged 10%, with installation practice the greatest variable. They reported measured supply-side leakages of 5–30%, and recommended a 10% value when estimating loads if all ducts are in unconditioned spaces.

The first mention of duct leakage in the ASHRAE Handbook was in the 1975 edition of the Equipment volume [5], which had

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two paragraphs on the subject. These paragraphs refer to duct leakage as "related to static pressure and joint type", and states that "if leakage is uncontrolled, energy will be wasted, and the system may fail to perform as specified". However, it also simply recommends that "transverse joints be sealed where static pressures are above (249 Pa) 1.0 in. water". This characterization of duct leakage implies an assumption that the ducts are put together well, and that the leakage is at seams and joints. There is no concern expressed about ducts that have been poorly installed, with possible partial or complete disconnects or poorly cut attachment holes. There is also no concern expressed about leaks at pressures on the order of typical residential systems, which usually have much lower pressures, even at the plenums.

By 1989, ASHRAE had added a section in the Handbook of Fundamentals regarding duct leakage [6]. This expanded on the discussion in the Equipment volume, and described different duct "leakage classes", where the duct leakage class is the leakage in cubic feet per minute (cfm) per (9.3 m^2) 100 ft^2 of duct surface area at a pressure of (249 Pa) 1.0 in. water. Mention is made of standards from as far back as 1972 to test the leakage of ducts. Again, however, there is an implied assumption that the leakage is at seams and joints.

It was in the latter half of the 1980s that measurement of duct leakage became more commonplace in existing homes. Some of the earliest documentation of the leakiness of residential duct systems can be found in Modera [7], Diamond [8], and Robison and Lambert [1]. The results of these studies are summarized, in terms of effective leakage area (ELA) are summarized in Modera [9]. These measurements raised the awareness that ducts often leak more than would be assumed based on their "leakage class", due to poor installation, failed connections, and failure of common sealing methods.

Though the tests available at the time were relatively primitive, and did not determine duct leakage under normal operating conditions of the conditioning system, these studies prompted further investigation of losses due to duct systems and the potential savings from retrofits. They also resulted in mathematical models being developed to estimate the duct efficiency based on several inputs. The first published model for duct efficiency was developed by Palmiter and Francisco [10,11] and modified by Francisco and Palmiter [12]. A similar model is the basis for a new ASHRAE standard on estimating the efficiency of thermal distribution systems [13]. These models showed that it is not enough to simply look at the leakage or the conduction. The various components of duct losses interact in complex ways. Therefore, detailed field measurements were required, both to establish the losses and potential savings and to validate the model.

The thermal efficiency of duct systems is often characterized by two different values. The first, and most simple, is the ratio of the conditioning energy delivered to the building through the registers to the conditioning energy put into the ducts by the conditioning equipment. This was referred to as the heat delivery efficiency by Palmiter and Francisco [10,11] and as the delivery effectiveness by ASHRAE [14]. The second measure of duct efficiency is the distribution efficiency. This includes more than the conditioning energy delivered through registers. It also includes such factors as recapture of duct losses and the effect of unbalanced duct leakage on the infiltration rate of the home. It is defined as the ratio of the energy required to heat the building if there were no duct losses to the actual energy required. This measure of efficiency does not include the efficiency of the conditioning equipment itself, but it does include losses on both the supply (positive pressure) and the return (negative pressure) side of the system.

The delivery effectiveness, η_{de}, is defined as:

$$\eta_{\mathrm{de}} = \frac{\sum_i Q_i \rho_i (h_i - h_{\mathrm{in}})}{W_{\mathrm{cap}}} \tag{1}$$

where i is an index that goes from 1 to the number of supply registers, Q_i the airflow rate through supply register i (m^3/h), ρ_i the density of air flowing through supply register i (kg/m^3), h_i the enthalpy of air flowing through supply register i (J/kg), h_{in} the enthalpy of the indoor air (J/kg), and W_{cap} is the measured capacity of the heating or cooling equipment (W). The power consumption that is required to meet heating and cooling loads in a building, W (W), is defined as:

$$W = \frac{W_{\mathrm{cap}}}{\eta_{\mathrm{dis}}\eta_{\mathrm{eq}}} \tag{2}$$

where η_{dis} is the distribution efficiency and η_{eq} is the equipment efficiency (both dimensionless).

Of the two duct efficiency metrics, delivery effectiveness is the easier to measure. With suitably accurate airflow, temperature, and humidity measurements at each of the registers, combined with a good estimate of the capacity of the conditioning equipment, this value can be calculated. For furnaces, the capacity of the equipment can be determined by measuring the energy input at the service meter and multiplying the input by the equipment efficiency. For electric furnaces, the equipment efficiency is assumed to be 1.0, whereas for combustion furnaces such as those utilizing natural gas and propane the combustion efficiency must be measured. For systems with compressors, it is necessary to use a combination of system airflow and temperature change across the coil (and, in cooling mode, humidity before and after the coil). Distribution efficiency, however, is much more difficult to measure. This is because the additional factors included in this value are not directly measurable. However, it is this efficiency measure that most directly relates to the total energy use, and therefore cost, required to condition a building.

This paper provides a large dataset of distribution efficiency that benchmarks duct efficiency in homes in the Pacific Northwest, provides data for duct efficiency and energy use models, and explores the value of duct retrofits. We present a series of studies that measured the distribution efficiency using a technique called short-term coheating. The short-term coheat test protocol alternates heating the house with the conditioning equipment and with space heaters. The space heater energy consumption represents the required heating energy with no duct losses. Therefore, by monitoring the energy consumption for both methods of heating it is possible to determine the distribution efficiency of the duct system.

Coheating, the procedure of alternately heating with two different types of heating equipment, was originally proposed by Socolow [15] as a means to investigate both the efficiency of heat delivery from the furnace and the heat loss rate of the building. The coheat methodology has been used to test the thermal performance of fireplaces [16] and to determine whole-house heat loss coefficients [17]. As energy conservation efforts highlighted the importance of duct efficiency in overall energy use, Larry Palmiter proposed the idea of using short-term coheat tests to measure duct efficiency over a single night. To the authors' knowledge, this is the first occurrence of the short-term version of the coheat methodology. The first publication of this technique was in the final report for a study that was done in the early 1990s [18]. This strategy involved alternating between heating with the furnace and duct system and heating with space heaters, with the space heaters controlled to maintain the same temperature distribution as was provided with the furnace. This methodology, when done overnight during periods of roughly constant meteorological conditions, minimizes thermal mass and solar gain effects and allows a direct comparison to between the energy required to heat the home with and without a duct system, and hence the thermal distribution efficiency.

In the early 1990s, the increasing focus on duct losses in the Pacific Northwest led to five studies of duct efficiency using the short-term coheat methodology. A summary of these tests are listed Table 1. All of these studies were carried out by Ecotope Inc. and resulted in technical reports [18–23] and conference papers [12,24–30]. Some of these tests included measurements of the improvements that resulted from sealing and/or insulating duct work. The goal of this paper is to summarize all of these tests and investigate the implications for residential duct efficiency and duct retrofits. Additional short-term coheat tests of duct efficiency were conducted on two homes by Andrews et al. [31], with the modification to the methodology that the furnace and heaters were each used for half of the night rather than switching back and forth between the two. One was a two-storey home with a basement, with a conditioning system in the basement and a separate conditioning system in the attic. This home had a distribution efficiency of 63%. The second home was a double-wide manufactured home that had a distribution efficiency of 70%.

2. Methodology

The basic principle of short-term coheat testing is to alternate back and forth approximately every 2–2.5 h between the ducted central furnace and ductless space heaters. The temperature in each heating zone (typically defined as any room location with a supply register) was maintained at the same level for both modes of operation by a control system and were measured with type-T constantan–copper thermocouples centered vertically within the room and located away from any obvious sources of heat loss or gain (duct registers, windows, etc.). Temperature measurements were also made in the supply and return duct system, in the supply registers, outside, and in all buffer spaces (attics, crawlspaces, garages, etc.). The thermocouples were connected to dataloggers (Campbell Scientific 21X) that executed the control software as well as performed data management.

The procedure of the test was to operate the furnace normally with a fixed set-point for a period of 2–2.5 h. The furnace thermostat was replaced with a damped thermocouple and the deadband was chosen such that the furnace would cycle approximately six times per hour (four times per hour for gas furnaces). In the studies after 1997, the thermostat thermocouple was replaced with a Honeywell T-87 thermostat because it gave better cycling performance. After the period of furnace operation, during which the furnace cycled normally, it was turned off for the next 2–2.5 h period for the coheating. During this coheating period, heating was controlled with space heaters located in each room. The individual space heaters would operate such that the temperature in each heating zone was maintained within 0.1 °C of the average temperature recorded during the previous furnace cycle. Maintaining these temperatures was critical to avoid heating and cooling of the thermal mass. After the period of space heater operation, the control logic would switch back to furnace operation. A minimum of four periods, two for the furnace and two for the space heaters, were completed for each test. The testing protocol was completed overnight to minimize solar gains and large swings in outdoor temperature. The electricity demand of the house was measured with true power meters (AO Sperry Model SPM-2012) that were attached at the main electrical panel. All measurements were made every second and recorded as 10 s average values.

The electrical demand of the house was analyzed by first determining the baseline electrical consumption. Although all obvious electrical loads were turned off for the duration of the test, a baseload of between 20 and 150 W of electrical demand typically remained. The distribution efficiency, η_{dis}, was then determined to be:

$$\eta_{\text{dis}} = \frac{W_{\text{heaters}} - W_{\text{baseload}}}{W_{\text{furnace}} - W_{\text{baseload}}} \tag{3}$$

where W_{heaters} is the average whole-house power consumption for the second half of the period that space heaters were

Table 1
Ecotope coheat studies of duct efficiency

Study name	Number of homes	Location	Type of residence	Duct retrofits	References
HEATAG	24	WA, ID, MT, OR	Site built	6	[18,19,24]
MAP	9	WA, ID	Manufactured—MAP Program	0	[20,25]
HUD	8	OR	Manufactured—HUD code	8	[21,26,27]
GAS	8	WA	Site built	6	[22,28]
ASH152	5	WA	Site built	0	[12,23,29,30]

Table 2
Floor areas and envelope air tightness

	n	Floor area (m^2)				Blower door airtightness at 50 Pa (ACH_{50})			
		Mean	Minimum	Median	Maximum	Mean	Minimum	Median	Maximum
HEATAG	24	156	73	157	252	9.6	2.9	9.2	15.7
MAP	9	133	79	158	189	4.6	3.2	4.2	7.5
HUD	8	111	77	110	158	14.5	10.6	14.6	21.5
GAS	8	159	114	146	245	10.2	6.3	10.7	13.7
ASH152	5	113	84	116	155	12.7	9.0	11.7	18.9

operating (including the baseload), $W_{baseload}$ the baseload power consumption, and $W_{furnace}$ is the average furnace output capacity plus baseload power consumption for the second half of the period of furnace operation. $W_{baseload}$ was typically a small correction (<1% of $W_{heaters}$). The second half of each period was used to avoid the transients that resulted from excess heat being thermosiphoned from the duct system during the first few minutes of the coheat period, and from the extra energy that was required to warm up the thermal mass of the HVAC system at the beginning of each furnace period.

In addition to the main short-term coheating tests, several other tests were completed, including blower door measurement of building air tightness (Energy Conservatory Model 3 with digital pressure gauge), pressurization testing of the interior and exterior leaks in the supply and return duct system (Energy Conservatory Duct Blaster), airflow measurement at the registers (Pacific Science Technology Fast-1 Flow Hood), air handler flow measurement (several techniques including hotwire anemometer, temperature rise, Energy Conservatory Duct Blaster Flow Matching, Energy Conservatory True Flow Plates). Additional tests that were carried out on some houses included an SF_6 tracer gas decay test, and the nulling and Delta-Q tests to measure duct leakage at operating conditions [30,32–34].

In some homes in some studies, duct retrofits were completed to determine the impact on duct efficiency. The retrofits consisted of an experienced contractor diagnosing duct leaks and applying duct mastic, fiberglass mesh, and mechanical fastening to remove air leakage. In some retrofits in the HUD study, severely compromised duct insulation was also replaced. Insulation was also added as appropriate in the GAS study. In addition, in half of the homes in the HUD study, a new technology for automating duct sealing [35] was used.

3. Results and discussion

3.1. Site characteristics

Table 2 shows some pertinent building characteristics. The minimum and maximum values are provided to show the range of house sizes tested, and the median is shown because of the small sample size. The HEATAG and GAS studies both included a number of larger, two-storey homes. The MAP study tested newer manufactured homes which are smaller, on average, than site-built homes, but still larger than the older manufactured homes tested in HUD. The ASH152 homes were of similar size to the older manufactured homes. The tightest homes in the sample were the energy-efficient manufactured homes in the MAP study. These homes were designed to have very little infiltration and to get their ventilation air from a mechanical ventilation system. The leakiest homes were the older manufactured homes in the HUD study.

3.2. Air handler flow

In order to model the impact of duct leakage on thermal efficiency, it is necessary to have an estimate of the flow through the system in order to calculate the capacity of some heating systems, to normalize the duct leakage flows, and to calculate conduction efficiencies of the ducts. Fig. 1 shows the air handler flows measured in four of the studies, for the number of homes n indicated beneath each study. In this figure, the "whiskers", which are the horizontal lines above and below the box, represent the largest values that are within approximately three standard deviations from the mean. In the event that there is a data point outside of three standard deviations, it is indicated by a small circle above or below the whiskers at the value of the data point. Air handler flow was not measured in the HEATAG study, which was done prior to the development of some of the required test equipment.

These results show that the majority of systems had between 0.38 and 0.47 m^3/s of air handler flow. Most of the systems that did not fall in this range had less flow, but no system in these

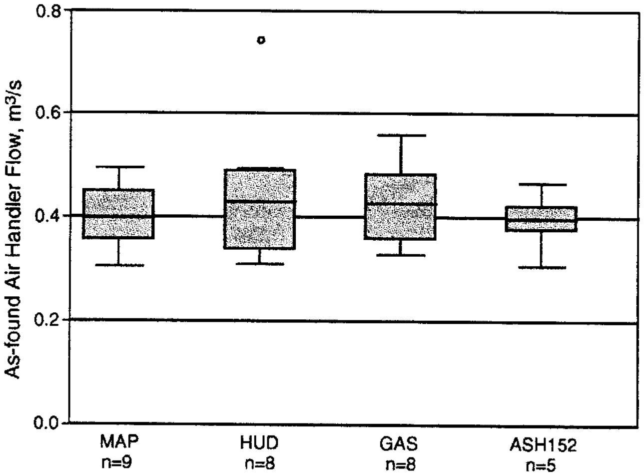

Fig. 1. Air handler flows for four studies. HEATAG study not included because the method of measuring air handler flow measurements used in the other studies was not yet developed.

studies had airflows below 0.3 m^3/s. The GAS houses tend to have somewhat more system flow, primarily because these houses were larger. The MAP homes have a similar range of air handler flow as the HUD homes despite being larger because the insulation characteristics are significantly better, allowing for smaller heating systems. There was one home in the HUD study that had a particularly large air handler flow, at nearly 0.75 m^3/s.

3.3. Duct leakage

Fig. 2 shows the duct leakage test results for supply leakage to outside at 25 Pa. This is different than leakage at operating pressures. Until recently there were no simple methods for measuring leakage at operating conditions in the field, and the standard technique for estimating duct leakage to outside was to measure it at an artificially induced pressure inside the ducts of 25 Pa relative to outside. Even in those studies where a better estimate of leakage to outside at operating conditions is available, the results are presented at 25 Pa to make it possible to compare across studies. Results are not available for the HEATAG study because it was not recognized at the time that it was important to differentiate between leakage to inside and leakage to outside. Also, the equipment typically used to perform these measurements was not available during the first phase of the project.

Fig. 2 suggests that the MAP homes had very low leakage levels compared to the rest of the homes, with the largest leakage about 0.045 m^3/s at 25 Pa reflecting the smaller HVAC system size and attention to duct sealing in the construction of these homes. Both the HUD and ASH152 studies have median leakages of about 0.094 m^3/s at 25 Pa. There is no distinct median line in Fig. 2 for the HUD study because there was a subset of these homes that all had leakage to outside of about 0.094 m^3/s at 25 Pa. The GAS homes had the largest median leakage at slightly more than 0.12 m^3/s at 25 Pa. Just as with air handler flow, the HUD homes had both the largest inter-quartile distance (i.e. the largest box) and the greatest range from minimum to maximum duct leakage at 25 Pa.

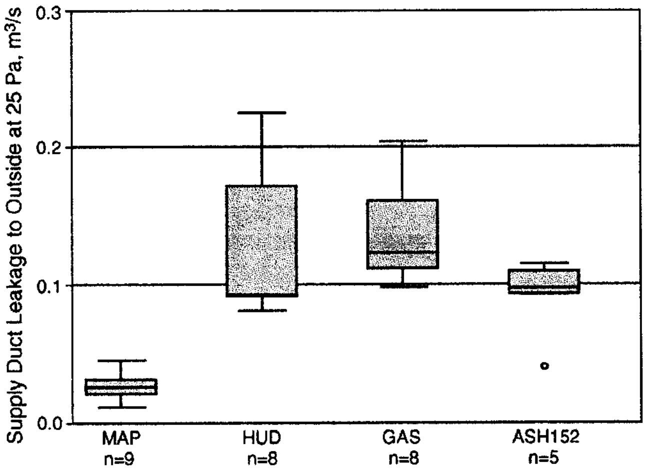

Fig. 2. Supply duct leakage. HEATAG study excluded because measurement techniques for separate supply and return leakage were not yet developed.

One feature of this graph is that the median is always significantly closer to the lower portion of the boxes, and that the lower whisker is always closer to the box than the upper whisker. This indicates that the majority of each set of homes had a leakage level that was relatively consistent, but that there were a few homes with much greater leakage. This reinforces the conclusion of other studies that leakage levels can vary widely across houses, and that the large leakage cases are represented by a small subset of homes with large, possibly catastrophic, leakage. These large leakage cases are often the result of disconnected ducts or other installation problems such as large gaps where smaller ducts take off from larger ducts.

3.4. Duct efficiency

Fig. 3 depicts both the measured pre-retrofit heat delivery efficiency and the pre-retrofit distribution efficiency for the five studies. One home in the HUD study did not have reliable results for the pre-retrofit distribution efficiency, reducing the number of cases shown in the figure from 8 to 7. The median heat delivery efficiency ranges from 51% for the ASH152 homes to 71% for the MAP homes. There is no heat delivery efficiency for the GAS study because heat delivery efficiency was not a major concern in this study, and most of the homes had too many registers to monitor all of them during the testing. The median distribution efficiency ranges from 64% for the GAS homes to 83% for the MAP homes.

In most of the studies, the difference between the medians is about 10 percentage points, with the distribution efficiency being greater. Distribution efficiency is usually larger because of the regain of heat from duct losses to buffer spaces to the conditioned space. It is possible to have distribution efficiencies lower than heat delivery efficiencies. This will occur when the supply leakage is sufficiently larger than return leakage, such that the house is depressurized. If the additional outdoor air that is then brought in to the home requires more conditioning than is recovered via regain from buffer spaces, the distribution efficiency will be lower than the heat delivery efficiency.

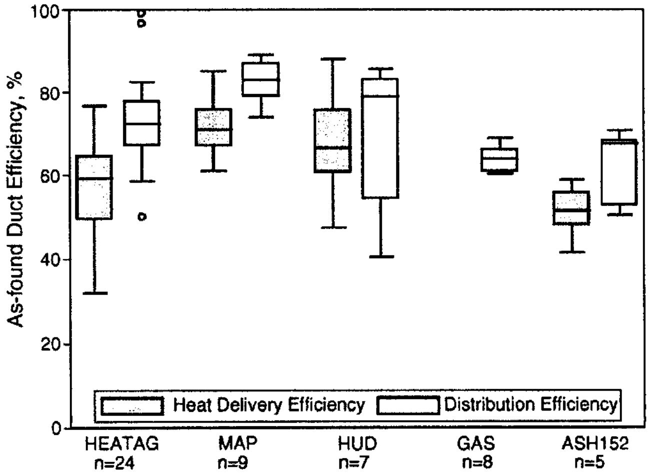

Fig. 3. As-found heat delivery and distribution efficiencies. Heat delivery efficiency was not measured in the GAS homes.

For each of the HEATAG and MAP studies, the mean percentage of "lost" heat (i.e. heat that is not delivered through the registers) that is recovered as useful heat by the house is between 35 and 40%. This amount of regain shows that assessing the performance of a heating unit based solely on the heat delivered through the registers will often exaggerate the problems associated with duct efficiency losses. However, if the heat is not delivered through the registers it is more likely that individual rooms will be cold, sometimes resulting in occupant complaints. The ASH152 homes had a much smaller percentage of the lost heat recovered by the house, at a mean of about 22%.

The HUD study had several homes with distribution efficiency lower than heat delivery efficiency, such that the overall mean recovery of lost heat is only about 7%. Since these homes are manufactured homes, there is no exterior return duct system and no return leakage. Having large supply leakage will then produce distribution efficiencies that are lower than the heat delivery efficiencies. The fact that the median distribution efficiency is higher than the median heat delivery efficiency in this study again shows the influence of a small subset of homes with catastrophic supply leakage. Even though the MAP homes are also manufactured houses, they do not have distribution efficiencies lower than heat delivery efficiencies. This is because the leakage levels are smaller, as shown in Fig. 2.

Fig. 3 shows that even the best homes (MAP) had a median heat delivery efficiency no greater than about 70%. Heat delivery efficiencies often dropped below 50–60%, with the worst individual house, in the HEATAG study, close to 30%. These results show that it is common for ducts to lose between 30 and 50% of the equipment capacity prior to exiting the registers, through a combination of leakage and conduction.

Based on median distribution efficiency for all studies, the energy losses typically range from 20 to 40%, even after factors such as "lost" heat recovered as useful heat by the home are considered. However, in one case in the HUD study losses were nearly 60%. This was a two-section (double-wide) home that had a crossover duct that was disconnected from the furnace, such that one entire half of the house was not getting conditioned air through the registers. On the other end of the efficiency spectrum, one site in the MAP study had the ducts located above the floor insulation for the home. This resulted in the highest MAP as-found heat delivery efficiency, 85%, and a distribution efficiency of 87%, with the majority of losses associated with leakage.

One question that has been the topic of some debate is the extent to which homes with basements recover lost heat. It is thought by some that basements recover nearly all of the heat because the basements are much better connected to the living space than the outdoors. The counter-argument is that the basements are still in significant thermal connection with the outdoors through the ground. In the HEATAG study, two homes with basements were evaluated. These two homes had distribution efficiencies near 100%, and are the two HEATAG outliers with high efficiency depicted in Fig. 3. These high efficiencies occurred despite the lower heat delivery efficiencies, meaning that nearly all of the heat from the furnaces was making it into the home as useful heat, even if it did not all come through the registers. While two homes are not sufficient to generalize, these results do suggest that homes with basements can recover nearly all of the lost heat.

Fig. 4 shows the improvement in distribution efficiency for the three studies at which duct retrofits were performed, which reduces the sample size in HEATAG from 24 to 6 homes. One home in each of the HUD (T06 pre) and GAS (G03 post) studies did not have reliable results for either the pre- or post-retrofit case, reducing the number of cases shown in Fig. 4 from 8 to 7. These results show that significant improvements were made in each of the studies. The median in the HUD study did not change significantly because the house that defined the median had very little actual improvement despite the fact that most of the leakage sites in the ducts were sealed. The pre-retrofit duct leakage to outside in this home was 0.093 m^3/s at 25 Pa, and the post-retrofit leakage was 0.018 m^3/s at 25 Pa. This indicates that, under normal operation, the leaks in this house were at low pressures, such that the impact is greatly overestimated by the leakage test at 25 Pa. All other homes in that study showed greater improvement. These results suggest the importance of duct leakage tests at operating conditions, such as those presented in Francisco et al. [32].

On average, the energy required to heat the homes decreased by about 16% in the HEATAG homes, corresponding to an average reduction by 44% of the efficiency loss. The HUD study showed very similar results, with an average reduction in space heating requirements of 16% and a reduction of efficiency loss by 43%. The GAS study showed about a 17% reduction in space heating required, which is very similar to the other studies, but this corresponded to only about a 36% reduction of efficiency loss despite the fact that insulation was added to many of the ducts in this study in addition to air sealing.

The majority of homes in the HEATAG and HUD studies had post-retrofit distribution efficiencies in excess of 80%. The majority of the GAS homes had post-retrofit distribution efficiencies between 70 and 80%. All houses that received

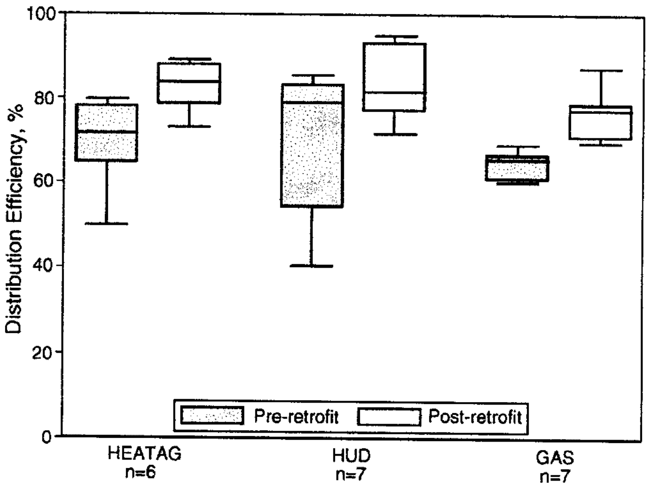

Fig. 4. Distribution efficiency before and after retrofits in the three studies that included repairs.

retrofits had final distribution efficiencies of at least 70%. For the two studies on site-built homes that are shown in Fig. 4, the majority of homes had post-retrofit distribution efficiencies that were higher than the highest pre-retrofit efficiencies within the same study. This was not the case in the HUD homes, despite the substantial improvements in efficiency following retrofit. This is partly a result of the ducts being within the belly space, which puts limits on the amount of air sealing that can be done and makes it difficult to add insulation.

These results show that targeted duct retrofits can result in substantial energy savings. However, they also show that even with these retrofits it is very difficult to completely eliminate measurable energy losses from these systems, highlighting the need to prevent problems via good installation.

4. Conclusions

Short-term coheating, though an admittedly challenging field methodology, has been extremely valuable. It is, to date, the only method of directly measuring the distribution efficiency of duct systems in homes, and can be an important mechanism for verifying retrofit effectiveness. These tests have also provided significant insight into the types of holes in ducts that lead to significant leakage and energy penalties, and other types and locations that can be sealed with little benefit.

The only other way to assess actual improvements due to retrofit is to use models that incorporate measured inputs to provide efficiency estimates. The results from these models are only as good as the input data. At this point, methods for obtaining the required inputs, particularly the duct leakage flows, are questionable. Even newer methods for estimating duct leakage at operating conditions can produce errors that may significantly skew the assessment of the retrofit, although improvements have been made in this area. Furthermore, measurement of duct surface area for purposes of assessing conduction losses can be time-consuming, and in some cases nearly impossible due to restricted access. The factors that differentiate distribution efficiency from delivery effectiveness are difficult to quantify independently.

Short-term coheat testing has been beneficial in the development of models. The tests have identified certain physical phenomena that play an important role in the overall energy consumption of conditioning systems, which helps to prioritize focuses of duct retrofit efforts. They have also provided a means of evaluating both the models and the methods for determining the inputs to the models [36]. As a result of this knowledge, it has been possible to implement the models into standards, such as ASHRAE Standard 152 [13].

The results of the short-term coheat testing on the types of houses evaluated in these studies show that homes often lose 20% or more of the heat provided by the conditioning equipment. All three studies that included retrofits showed a reduction in heating energy of about 16%, corresponding to a reduction in efficiency loss of 35–45%. This result cannot be extrapolated to all homes, because these homes are all from one region in the United States and were typically selected to have significant leakage to outside. However, the short-term coheat testing has been effective at verifying that targeted duct retrofits can result in substantial energy savings, despite the fact that noticeable losses remain.

Short-term coheat testing has also shown that a significant fraction of heat that is lost by the ducts before reaching the registers can be recovered as useful heat by the house. This difference between the total useful heat and the heat that actually enters the home via the registers shows that efforts to identify homes with major efficiency losses by focusing on the registers may often be misguided and lead to substantial attempts to improve ducts with little realized improvement. Short-term coheating has also verified that it is possible to have overall distribution efficiencies less than what is apparent based on the heat that comes through the registers due to the increase in load from induced outside air infiltration.

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September 30, 2009

Bonnie Ziemann
Deputy Director
Nebraska Energy Office
P.O. Box 95085
Lincoln, NE 68509

RE: 2009 International Energy Conservation Code Incremental Cost Report
Funding Source: U.S. Department of Energy, CFDA# - 81.041

Disclaimer: This report was prepared with the support of the U.S. Department of Energy (DOE) Grant #DE-FG-26-07NT43200. The findings, conclusions and recommendations herein are those of the author and do not necessarily reflect the views of DOE.

Approach: This letter discusses cost impacts associated with upgrading the Nebraska State Energy Code from the current 2003 International Energy Conservation Code (IECC) to the 2009 IECC. It is based directly on our recently completed report: *Energy Impact Study of the 2003 IECC and 2009 IECC Energy Codes for Nebraska*. This report focused on the energy use impact of updating Nebraska's residential energy code.

The item-by-item differences between the 2003 and 2009 codes and the cost impact of each are discussed below. An important difference between the codes is that the 2003 code divides the state into three distinct climate zones (represented by Omaha, Norfolk and Chadron) with different requirements, while the 2009 code has uniform requirements throughout the state. Also, the 2003 code requires higher levels of insulation for homes with more windows, while the 2009 code does not. Therefore, the 2009 code has more uniform requirements and may be easier to implement for builders who cover multiple cities or use varying window percentages.

Cost estimates were obtained from three sources:

- RSMeans Cost works online – Residential edition, 2009 data for residential new construction in Omaha, NE.
- EPA report: "Energy Star Qualified Homes 2011 Savings and Cost Estimate Summary" available online at: http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/2011_Savings_Cost_Summary.pdf
- Home Depot web site – provides online pricing available to customers nationwide. Online pricing often mirrors pricing available in national chain home improvement stores.

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Exterior wall insulation:

The ***2009 IECC*** requires either R-20 exterior walls or R-13+5. R-20 can be achieved with an R-21 batt in a 2x6 exterior wall. R-13+5 means that a 2x4 wall with R-13 (such as a fiberglass batt) is combined with an exterior insulated sheathing product having an R-value of 5 that covers at least 75% of the exterior wall. Therefore, the 2009 IECC requirements can be met statewide using either of these methods.

The ***2003 IECC*** requires R-21 or higher for all homes in the Norfolk and Chadron climate zones. This essentially requires a 2x6 wall to be used. The 2003 code allows homes in Omaha with under 15% window to wall ratio to be constructed with R-18 walls. This can be accomplished using either a 2x4 wall with an R-13 batt plus R-5 exterior insulation or using a 2x6 wall with R-19 fiberglass batts.

Net change: The 2009 code allows all homes in the state to be constructed using a minimum of 2x4 walls with R-13 fiberglass batts with R-5 insulated sheathing. This is the same as the least stringent requirement throughout the state under the 2003 code. The construction cost does not change for homes in Omaha with under 15% window to wall ratio, and could be lower for all other homes in the state.

Cost example: For the 1852 sf ranch home in the energy study (with 2000 sf exterior wall area), RSMeans installed costs including Overhead and Profit (O+P) are as follows: $4,326 for 2x4 framing, R-13 fiberglass batts, and R-5.4 isocyanurate rigid insulation OR $5,082 for 2x6 framing, R-21 fiberglass batts, and 1/2 inch OSB exterior sheathing. For homes that would have required R-21 exterior walls under the 2003 IECC, there would be a potential $756 construction cost savings under the 2009 IECC.

Basement wall insulation:

The ***2009 IECC*** requires either R-10 continuous basement wall insulation or R-13 insulation in a framed cavity. R-10 continuous insulation could be achieved using a rigid board product on the interior or exterior of the wall. R-13 cavity insulation is most often obtained using R-13 fiberglass batts in a 2x4 cavity.

The ***2003 IECC*** requires between R-10 and R-15 basement wall insulation. The Omaha requirement is R-10 and most other homes in the state require R-11. This could be met using an R-11 batt in a 2x4 framed cavity.

Net change: If continuous rigid board insulation is used, the 2009 IECC allows homes across the state to use the current minimum statewide insulation level under the 2003 IECC. Therefore there would be no cost increase and there could be a construction cost savings in some areas. If framed cavity insulation is used, both codes can be met using a 2x4 wall. Most homes in the state would need to upgrade from R-11 to R-13 fiberglass batts.

Cost example: RSMeans cost data list exactly the same installed cost for R-11 and R-13 fiberglass batts ($0.58 per sf). Both types of batt have the same thickness and do not require different framing methods. Therefore, there is no change in cost for most homes built in the state. Where R-15 insulation was required under the 2003 IECC, there would be a construction cost reduction from $0.65 to $0.58 per square foot. For the 1852 sf ranch (with 1600 sf of basement wall), this would be a savings of $112.

Ceiling insulation:

The ***2009 IECC*** requires R-38 insulation in ceilings state-wide. This can be accomplished using R-38 fiberglass batts (10" to 12" thick) or with blown-in insulation. The ***2003 IECC*** requires R-49 insulation in most ceilings throughout the state. R-38 ceilings are allowed for homes in the Omaha climate zones with less than 15% window to wall ratio. R-49 insulation can be accomplished with blown-in insulation or with a combination of batts and blown-in insulation.

Net change: For homes in Omaha with less than 15% window to wall ratio, there is no change. All other homes in the state would see a construction cost savings under the 2009 IECC as the insulation is reduced from R-49 to R-38.

Cost example: The 1852 sf ranch home has 1852 sf ceiling area. Using RSMeans cost data for blown fiberglass attic insulation, the installed cost including O+P is $2,883 for R-38 insulation and $3,622 for R-49. This would be a $739 construction cost savings for most homes built in the state.

Floor insulation:

The ***2009 IECC*** requires R-30 insulation for all floors over unconditioned spaces – including garages, cantilevered floors and floors over unconditioned basements or crawlspaces. This can be met using a 9" fiberglass batt in a 2x10 floor cavity. The code also allows less than R-30 to be used if it fills the entire floor cavity, so the only construction cost increase is for the insulation itself – no changes to the structure are required to accommodate increased insulation.

The ***2003 IECC*** requires between R-19 and R-30 insulation depending on the location and window to wall ratio. Most homes currently being built in Nebraska require R-21 floor insulation. This can be accomplished using a 5.5" R-21 fiberglass batt.

Net change: Because the code does not require structural upgrades to accommodate additional insulation, the only added construction cost is for the insulation itself. The 2009 IECC would require most homes with insulated floors to upgrade from an R-21 floor to an R-30 floor. However, most homes in Nebraska are constructed with conditioned basements and have very little insulated floor area. Therefore, the statewide impact of this change is likely to be minimal.

Cost example: The 1852 sf home used in the energy study has no floors over unconditioned space since it was modeled with a conditioned basement having insulation on the walls. If the home had an unconditioned basement, it would have 1852 sf of floor area. RSMeans cost data does not provide pricing for R-21 batts in floors, but it would be only incrementally higher than the cost for R-19 batts in floors. The cost to install R-19 insulation in this home's floor would be $1,996, and the cost to install R-30 insulation in the floor would be $2,495. Therefore, homes that had unconditioned basements would experience an added construction cost of $499. In this case, the walls of the basement would not also need to be insulated, saving approximately $0.58 per square foot of basement wall.

Programmable thermostats:

The ***2009 IECC*** requires programmable thermostats be installed for all homes having furnaces, but does not require them for homes with heat pumps.

The ***2003 IECC*** has no requirement for programmable thermostats.

Net change: All homes with furnaces would need to install a programmable thermostat under the 2009 code.

Cost example: RSMeans cost data lists installed costs for non-programmable thermostats as $71.41 and for programmable thermostats as $145.69. RSMeans uses the same labor cost for the two types – the only difference in their listed cost is for materials. RSMeans indicates a $26.92 material cost for non-programmabe and $94.72 for programmable. These numbers do not seem to match widely available prices in the marketplace. The Home Depot web site lists non-programmable thermostats ranging from $8.97 to $29.98 and programmable thermostats that would meet the code requirement ranging from $19.98 to $99.99. However, most of the more expensive models are designed to work with heat pumps, and the new code does NOT require programmable thermostats to be used with heat pumps. The 2011 Energy Star qualified homes cost estimate includes an estimated premium of $19.00 for programmable thermostats. Based on marketplace prices, I feel that the Energy Star estimate is accurate.

Energy efficient lighting:

The ***2009 IECC*** requires that high-efficacy lighting be used for 50% of installed lamps. The least expensive means of meeting this requirement is to use screw-base replacement compact fluorescent (CFL) light bulbs.

The ***2003 IECC*** has no requirement for high-efficacy lighting.

Net change: The 2009 code would require CFL bulbs to be installed in 50% of the home.

Cost example: A home with eight rooms, having an average of three light bulbs installed per room would be delivered with 24 total lamps. RSMeans does not list cost data for lamps. The Home Depot web site lists a cost of $35.89 for a package of 120 60-Watt incandescent lamps and a cost of $149.82 for a package of 72 13-Watt (60 Watt light output equivalent) compact fluorescent lamps. This is a cost difference of $1.78 each. To replace twelve lamps, the total increased cost would be less than $22.

Duct sealing and testing:

The ***2009 IECC*** has requirements for duct leakage that can be met/demonstrated in one of four ways: (1) Postconstruction duct blaster testing demonstrating leakage to outdoors of less than 8 cfm/100 sf of conditioned floor area; (2) Rough-in duct blaster testing demonstrating total duct leakage less than 6 cfm/100 sf of conditioned floor area performed with the air handler installed; (3) Rough-in duct blaster testing demonstrating total duct leakage less than 4 cfm/100 sf of conditioned floor area performed without the air handler installed; or (4) no testing is required if the air handler and all ducts are located inside conditioned space.

The ***2003 IECC*** requires duct sealing, but has no testing requirement, thus the requirement has been largely unenforced.

Net change: Many homes in Nebraska have all or part of the HVAC system located inside conditioned space. When this is the case, there is no cost increase associated with this requirement. For homes with systems installed outside conditioned space, there may be cost increases associated with properly air sealing ductwork. A duct blaster test will also be required.

Cost example: RSMeans does not list costs for duct sealing and testing. However, this has been addressed in the Energy Star 2011 Cost Estimate. That report estimates an additional cost of $100 per 1000 sf of conditioned space for duct sealing and testing to meet a similar airtightness requirement. For the 1852 sf ranch home, this would add $185 in additional cost.

Air sealing and testing:

The ***2009 IECC*** contains new requirements for air leakage and air sealing. The air sealing items are similar to those required by the current Energy Star thermal bypass checklist. There are two ways to meet the requirement: (1) testing – perform a blower door test and obtain results of less than 7 air changes per hour when tested at 50 Pa pressure. Or (2) using a checklist to perform a visual inspection to verify air sealing and the presence of air barriers, performed by a code official or approved third party independent of the installer of the insulation.

The ***2003 IECC*** does not include an air sealing or testing requirement.

Net change: Homes would have to demonstrate airtightness using either a blower door test or through the use of a checklist of air sealing items.

Cost example: RSMeans does not list costs for blower door testing or air sealing. However, the Energy Star 2011 Cost Estimate report does list a cost of $250 to comply with the current thermal bypass checklist. This cost includes materials and labor to meet the checklist and third party verification of the items. The cost to instead perform blower door testing would likely be similar.

Summary:

The table below summarizes expected cost changes for the 1,852 sf ranch-style house.

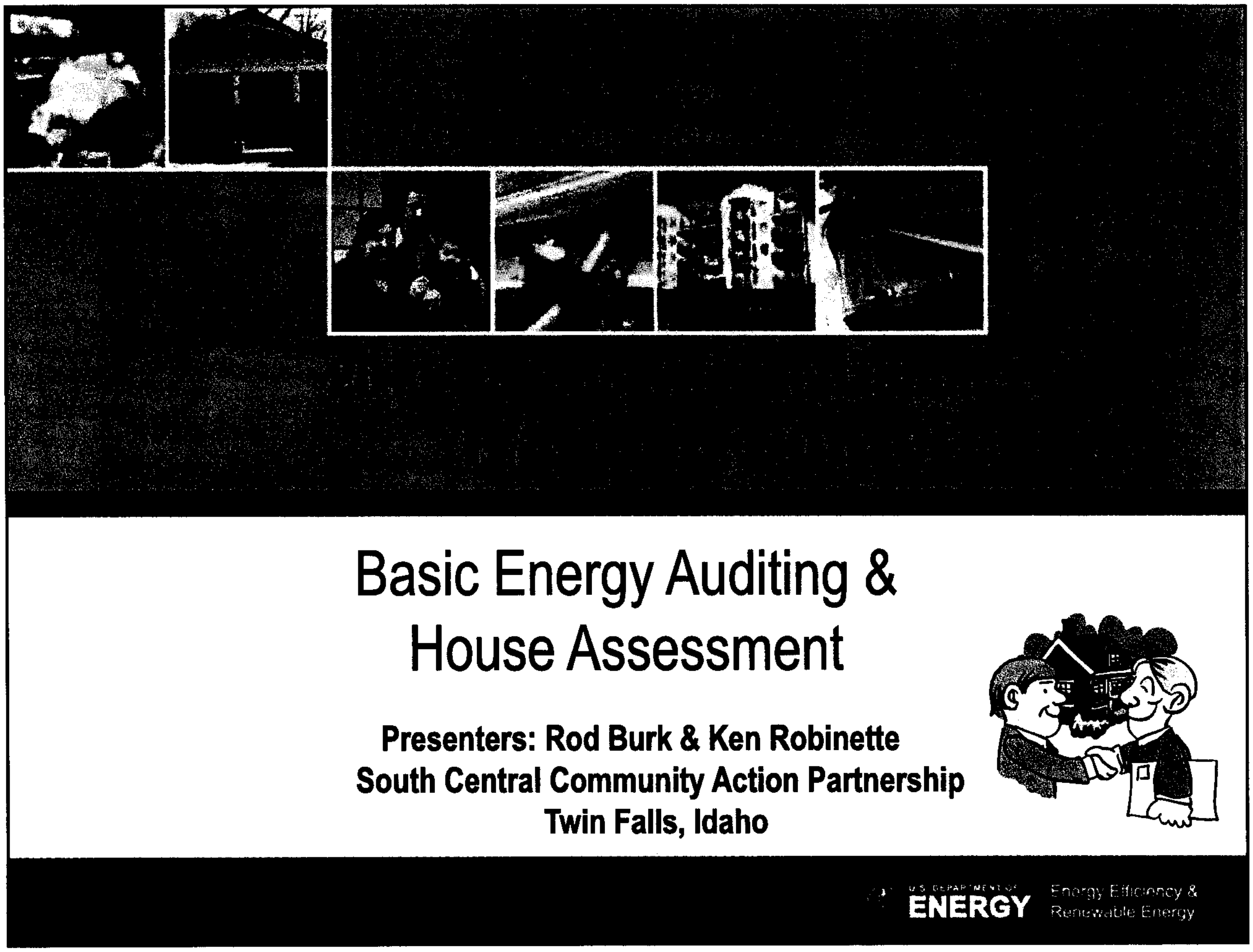
Code Change	Construction Cost Change	Notes
Exterior walls	$0 to -$756	$0 for Omaha homes with 15% window to wall ratio
Basement walls	$0 to -$112	$0 for all homes except Chadron 18% window to wall ratio
Ceiling	$0 to -$739	$0 for Omaha homes with 15% window to wall ratio
Floor	+$499	Not applicable to most NE homes – only required if basement unconditioned

Programmable thermostat	+$19	Required for all homes.
High efficacy lighting	+$22	Required for all homes.
Duct sealing and testing	+$185	Required for all homes.
Air sealing and testing	+$250	Required for all homes.
Estimated total (Omaha, 15% window to wall ratio, conditioned basement)	+$476	$476 additional construction cost for 2009 IECC
Estimated total (all cities, 18% window to wall ratio, conditioned basement)	-$1,019	$1,019 reduced construction cost for 2009 IECC

As the table above shows, for the example 1852 sf home constructed in Omaha with 15% window to wall ratio and a conditioned basement, the total estimated increase in construction cost is $476 if the 2009 IECC is adopted. The energy study showed that this same home could expect to experience $164 in annual energy savings, providing a less than 3 year simple payback for the homeowner. In most other cities, and in Omaha homes with a window to wall ratio greater than 18%, the construction cost for the 2009 IECC is actually lower than for the 2003 IECC. Since the energy study also showed energy savings for those cases, this provides instant payback for the typical homebuyer.

Sincerely,

Amy Musser
Vandemusser Design, LLC



Basic Energy Auditing & House Assessment

Presenters: Rod Burk & Ken Robinette
South Central Community Action Partnership
Twin Falls, Idaho

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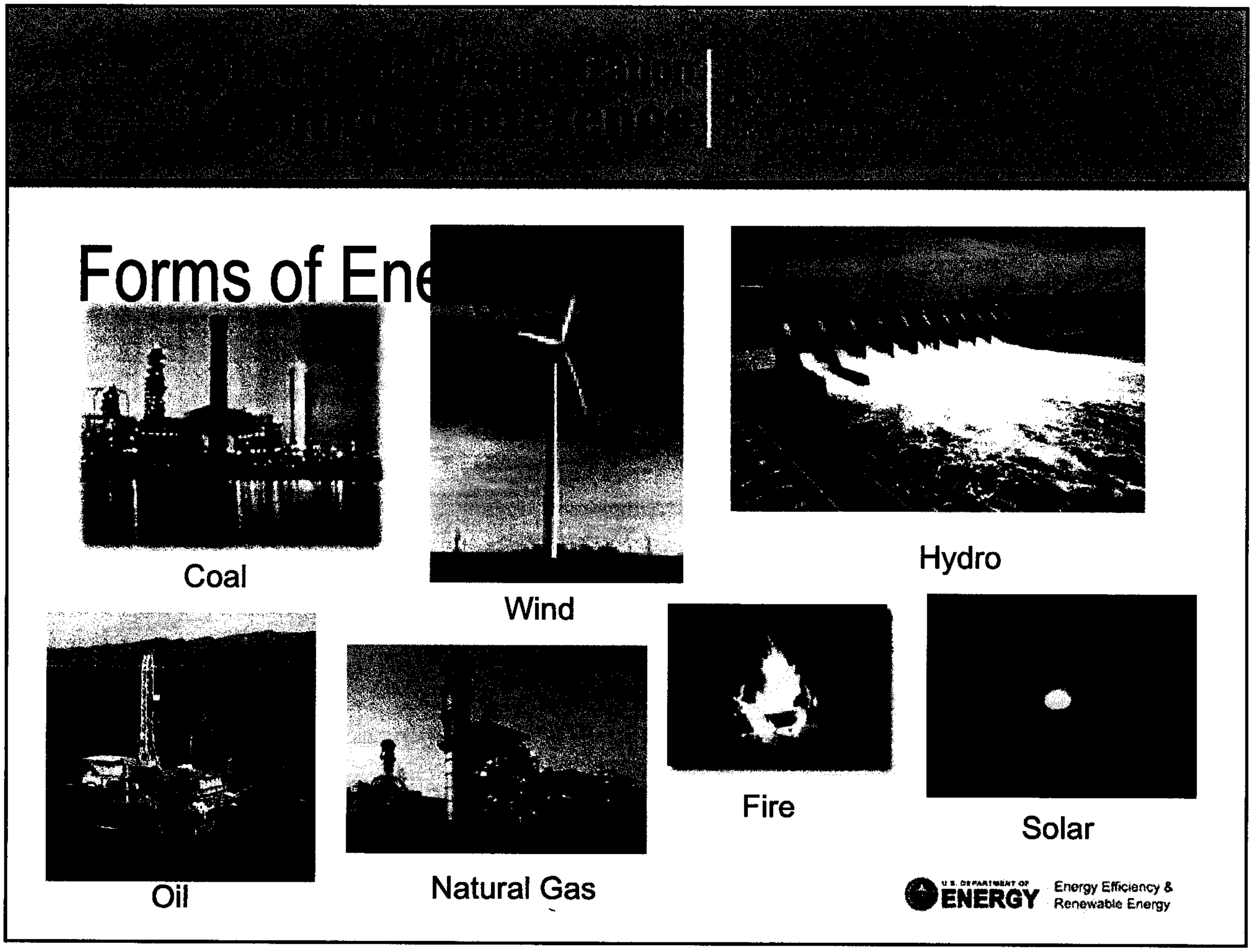


Forms of Ene

Coal

Wind

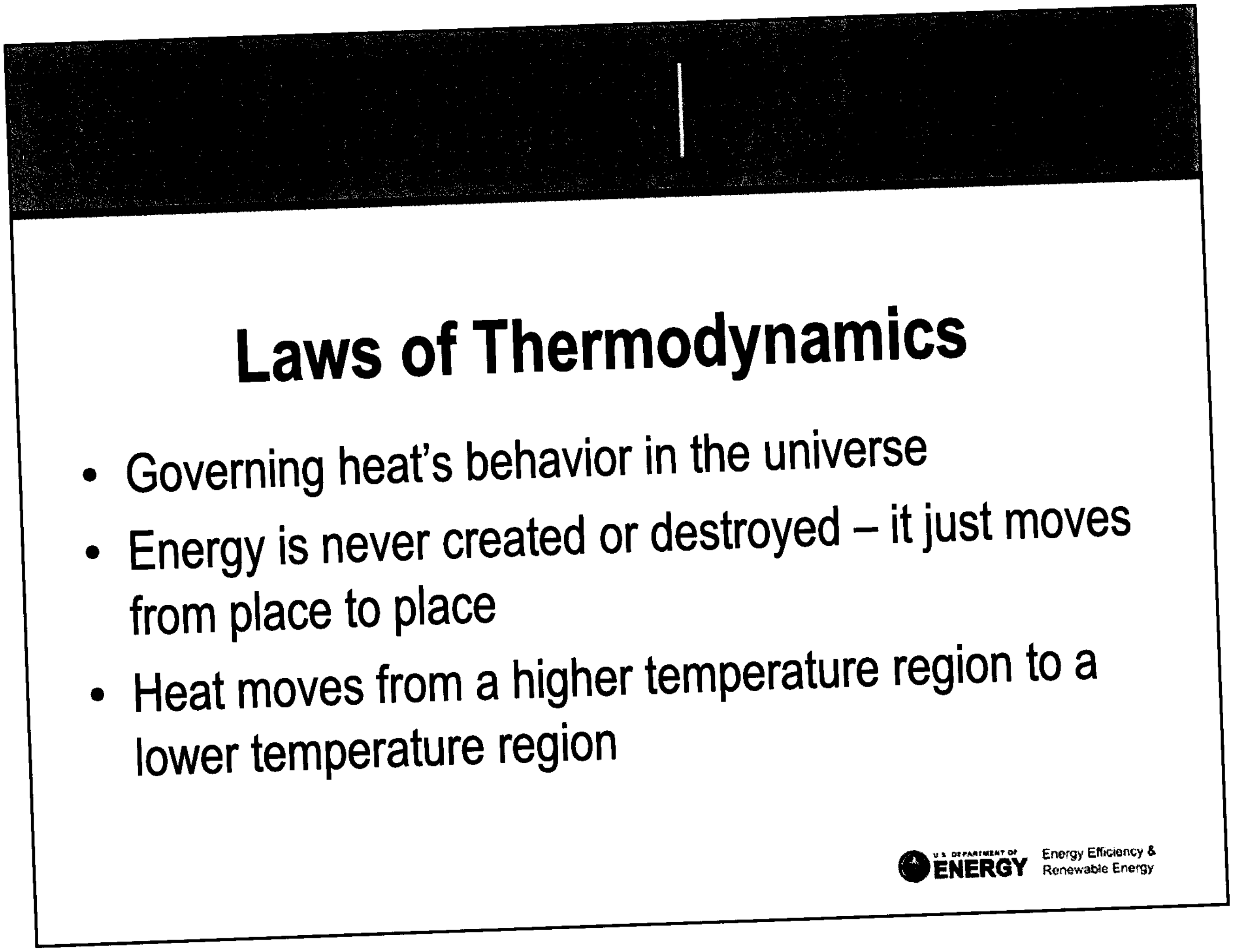
Hydro

Oil

Natural Gas

Fire

Solar



Laws of Thermodynamics

- Governing heat's behavior in the universe
- Energy is never created or destroyed – it just moves from place to place
- Heat moves from a higher temperature region to a lower temperature region

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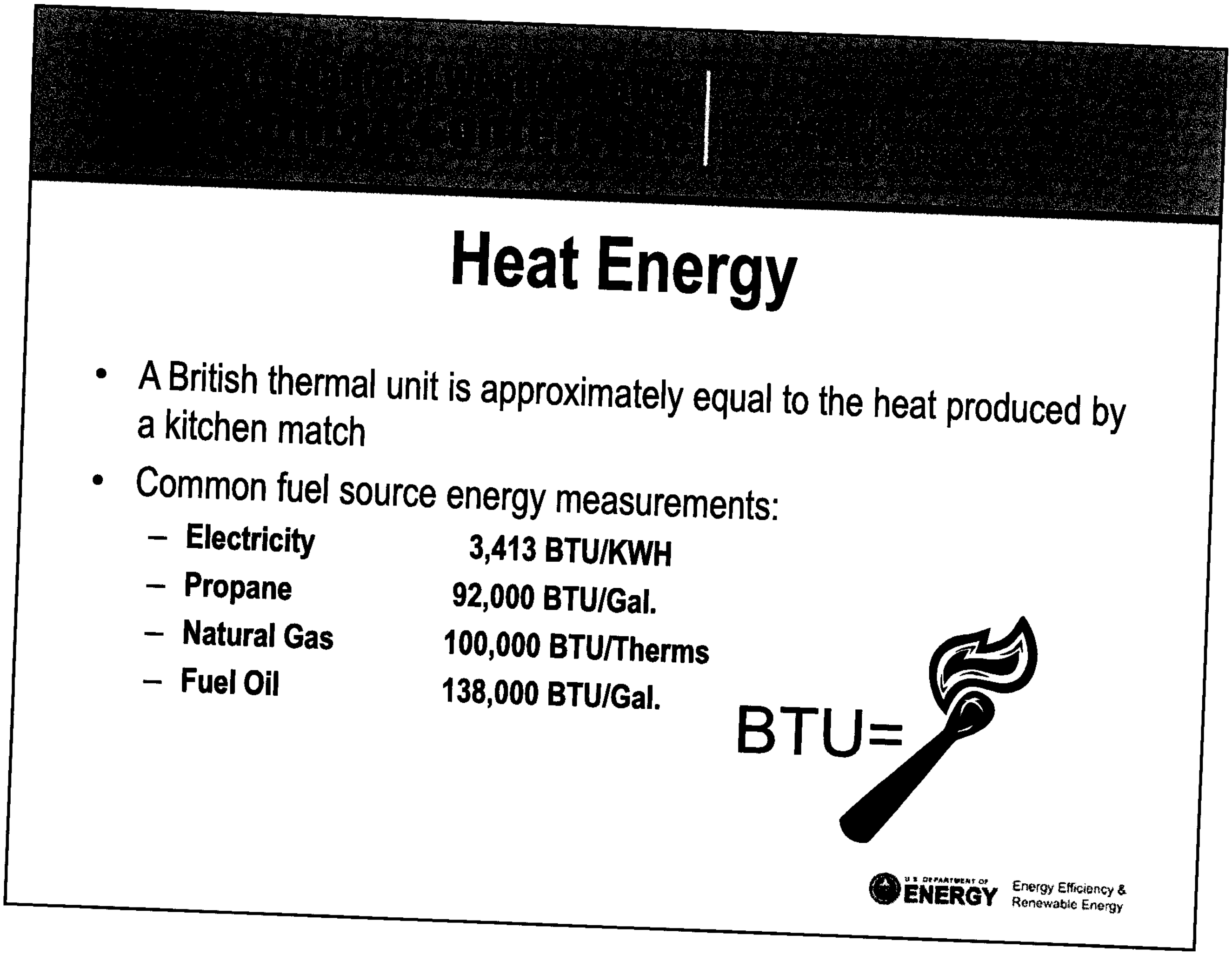

Heat Energy

- A British thermal unit is approximately equal to the heat produced by a kitchen match
- Common fuel source energy measurements:

– **Electricity**	**3,413 BTU/KWH**
– **Propane**	**92,000 BTU/Gal.**
– **Natural Gas**	**100,000 BTU/Therms**
– **Fuel Oil**	**138,000 BTU/Gal.**

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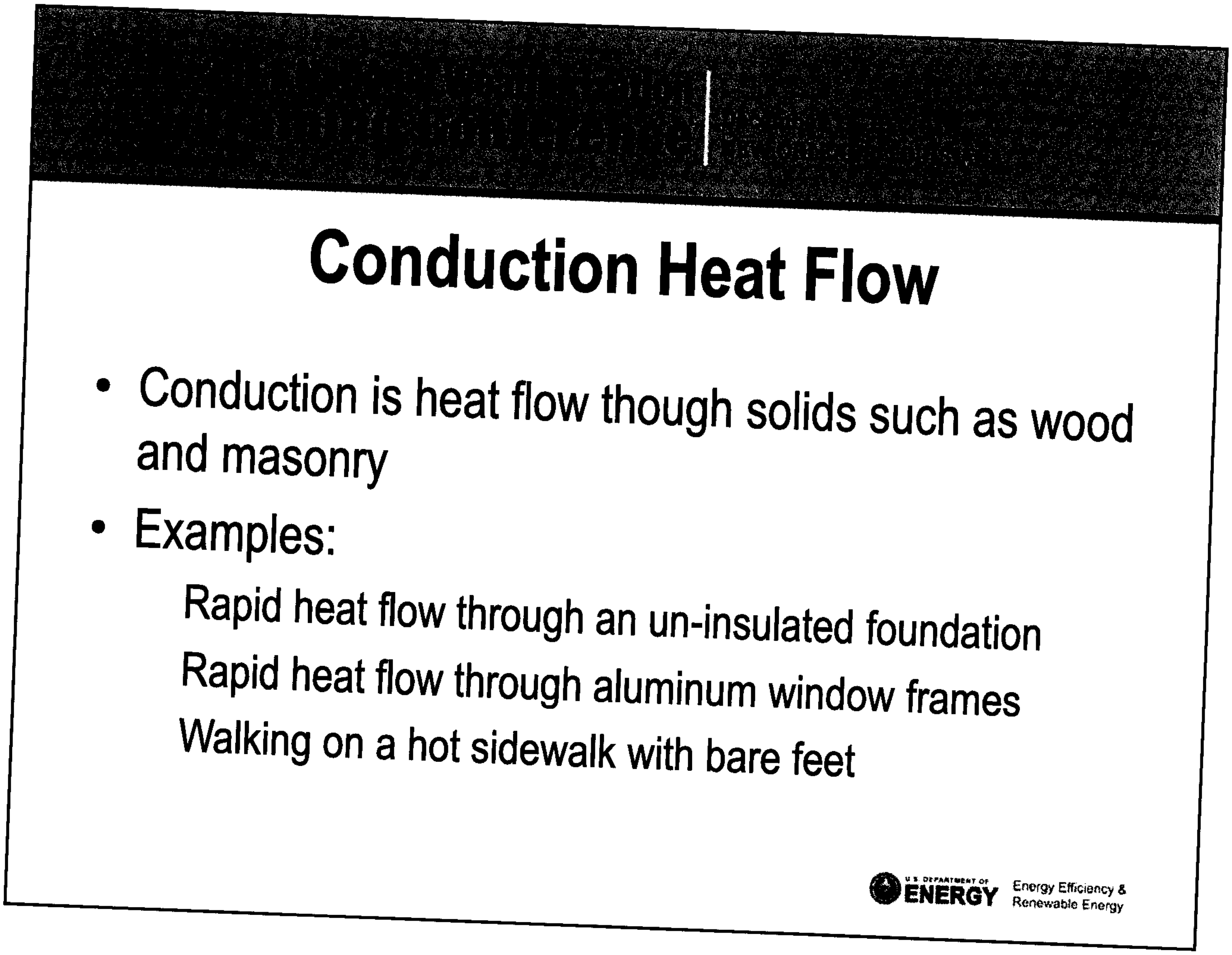
Three Types of Heat Flow

- **Conduction**

  Heat transport molecule to molecule in a solid
- **Convection**

  Heat transport by movement in a fluid
- **Radiation**

  Heat waves traveling through space



Conduction Heat Flow

- Conduction is heat flow though solids such as wood and masonry
- Examples:

  Rapid heat flow through an un-insulated foundation
  Rapid heat flow through aluminum window frames
  Walking on a hot sidewalk with bare feet

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Convection Heat Flow

- Convection is heat flow in fluids such as air or water
- Common examples:
    - Downdrafts at windows during the winter
    - Operation of a gas water heater
    - Convection currents between primary window and storm window

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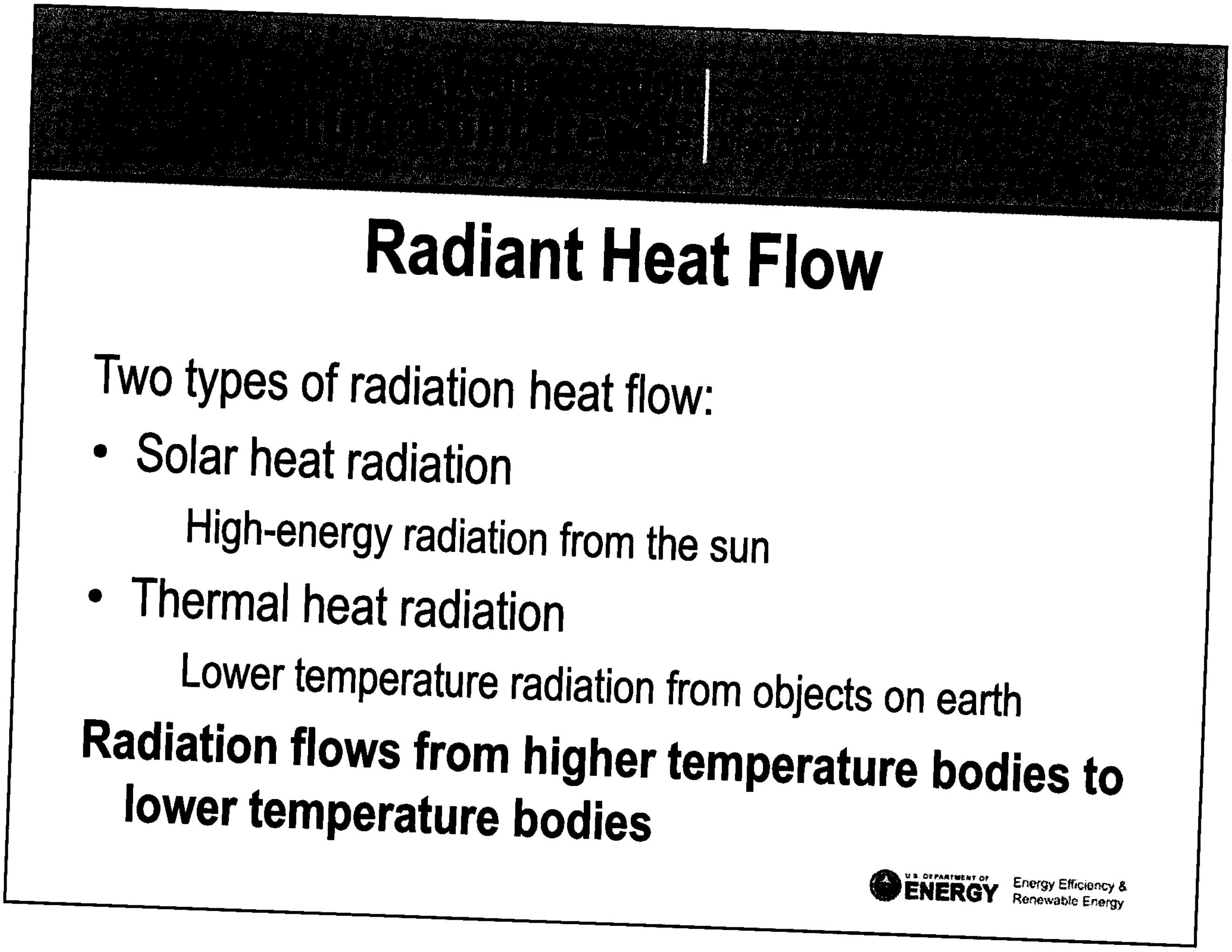

Radiant Heat Flow

Two types of radiation heat flow:

- Solar heat radiation

  High-energy radiation from the sun

- Thermal heat radiation

  Lower temperature radiation from objects on earth

Radiation flows from higher temperature bodies to lower temperature bodies

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Heat Flow in Buildings

- **Transmission heat flow**
  - Ceiling transmission
  - Wall transmission
  - Floor/foundation transmission
  - Window/door transmission
- **Air Flow**
  - Mechanical ventilation
  - Air leakage

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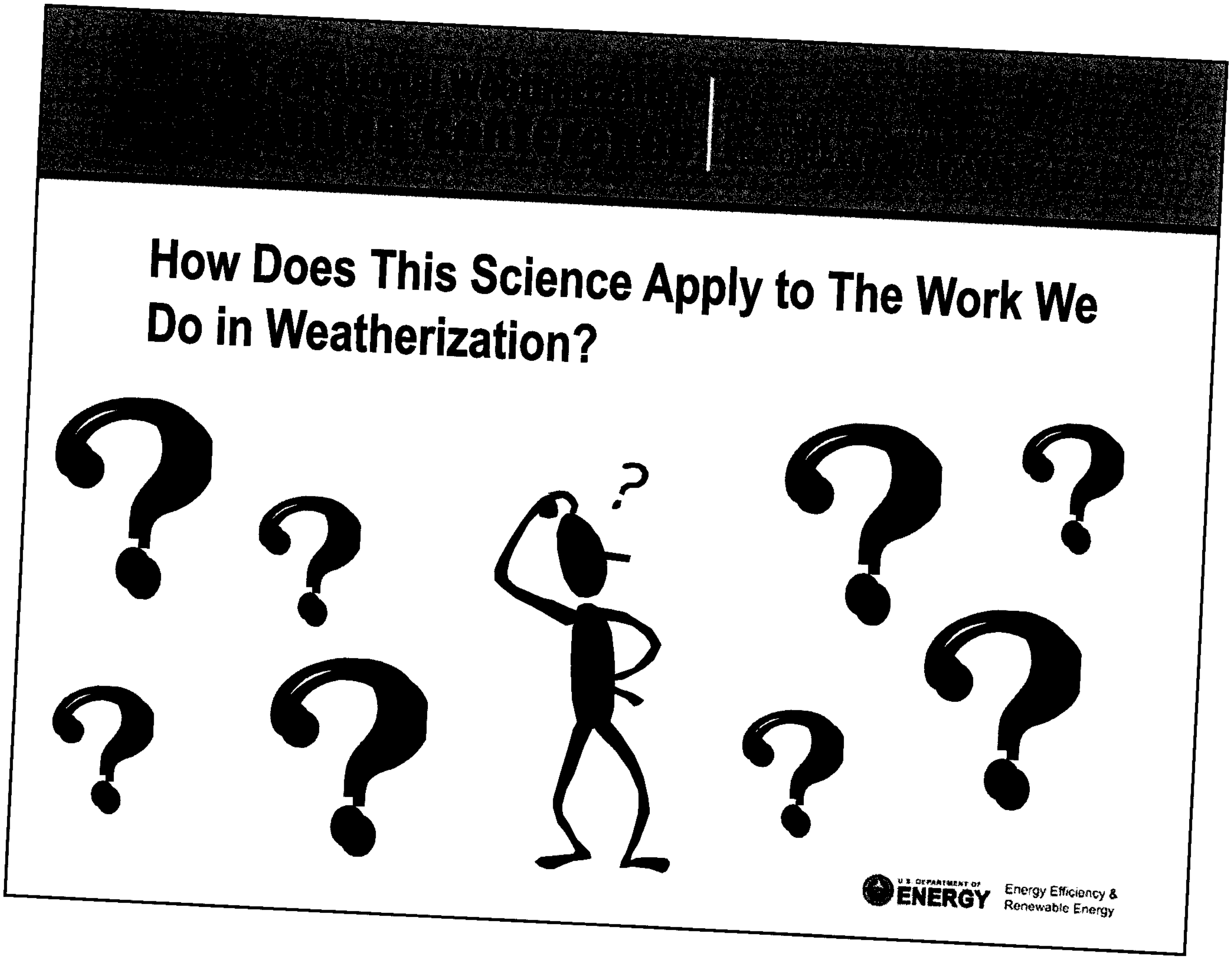

How Does This Science Apply to The Work We Do in Weatherization?

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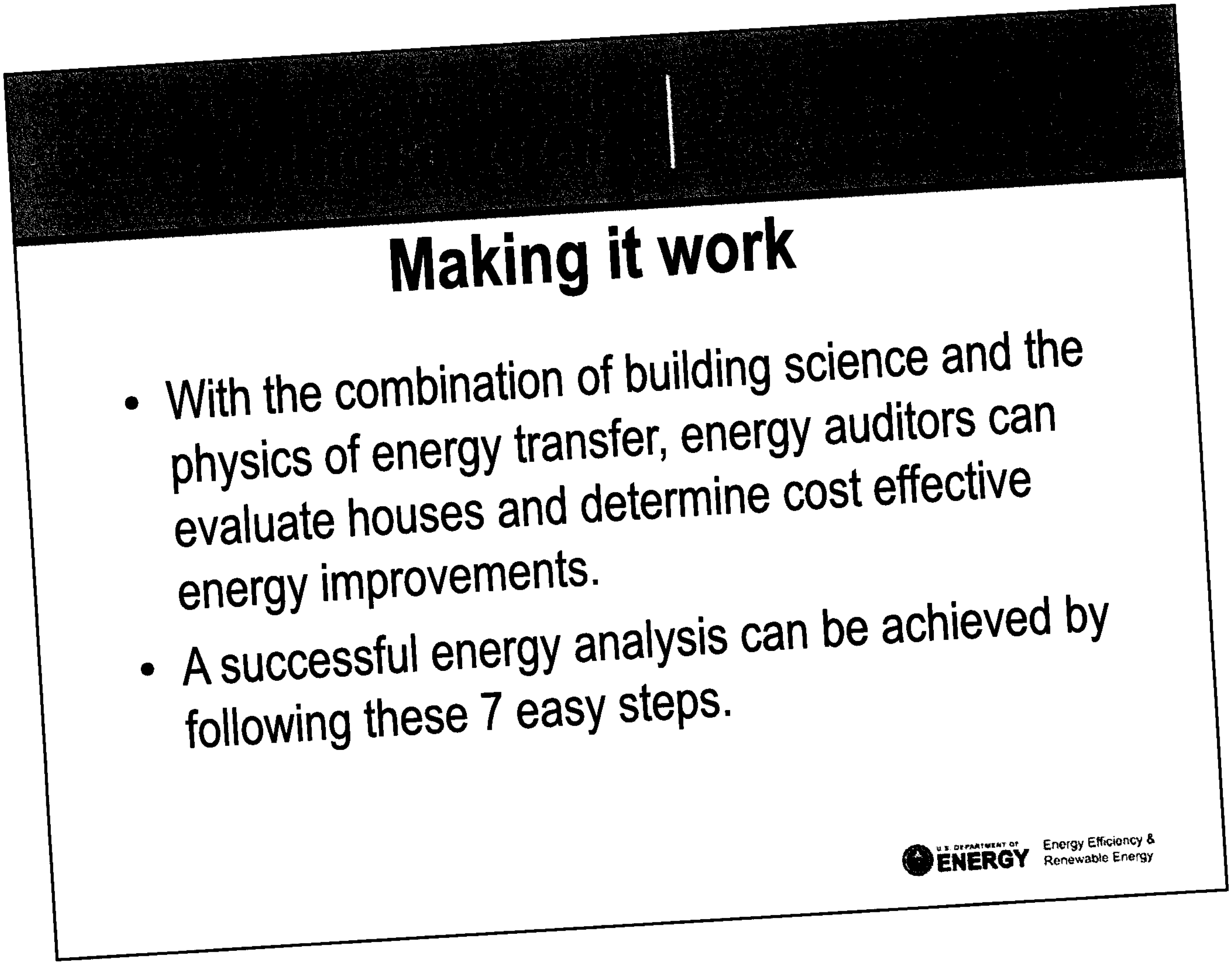

Making it work

- With the combination of building science and the physics of energy transfer, energy auditors can evaluate houses and determine cost effective energy improvements.
- A successful energy analysis can be achieved by following these 7 easy steps.

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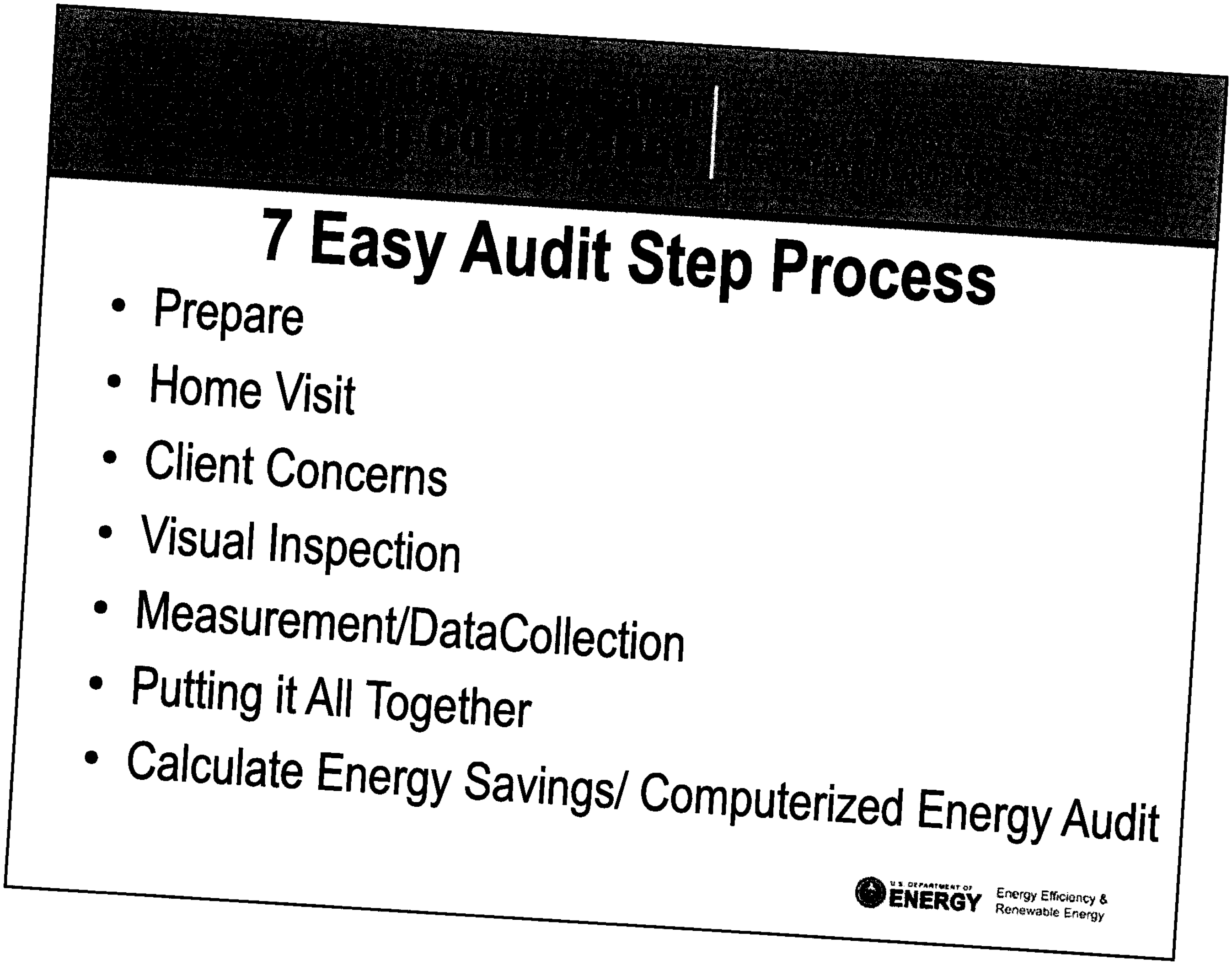

7 Easy Audit Step Process

- Prepare
- Home Visit
- Client Concerns
- Visual Inspection
- Measurement/DataCollection
- Putting it All Together
- Calculate Energy Savings/ Computerized Energy Audit

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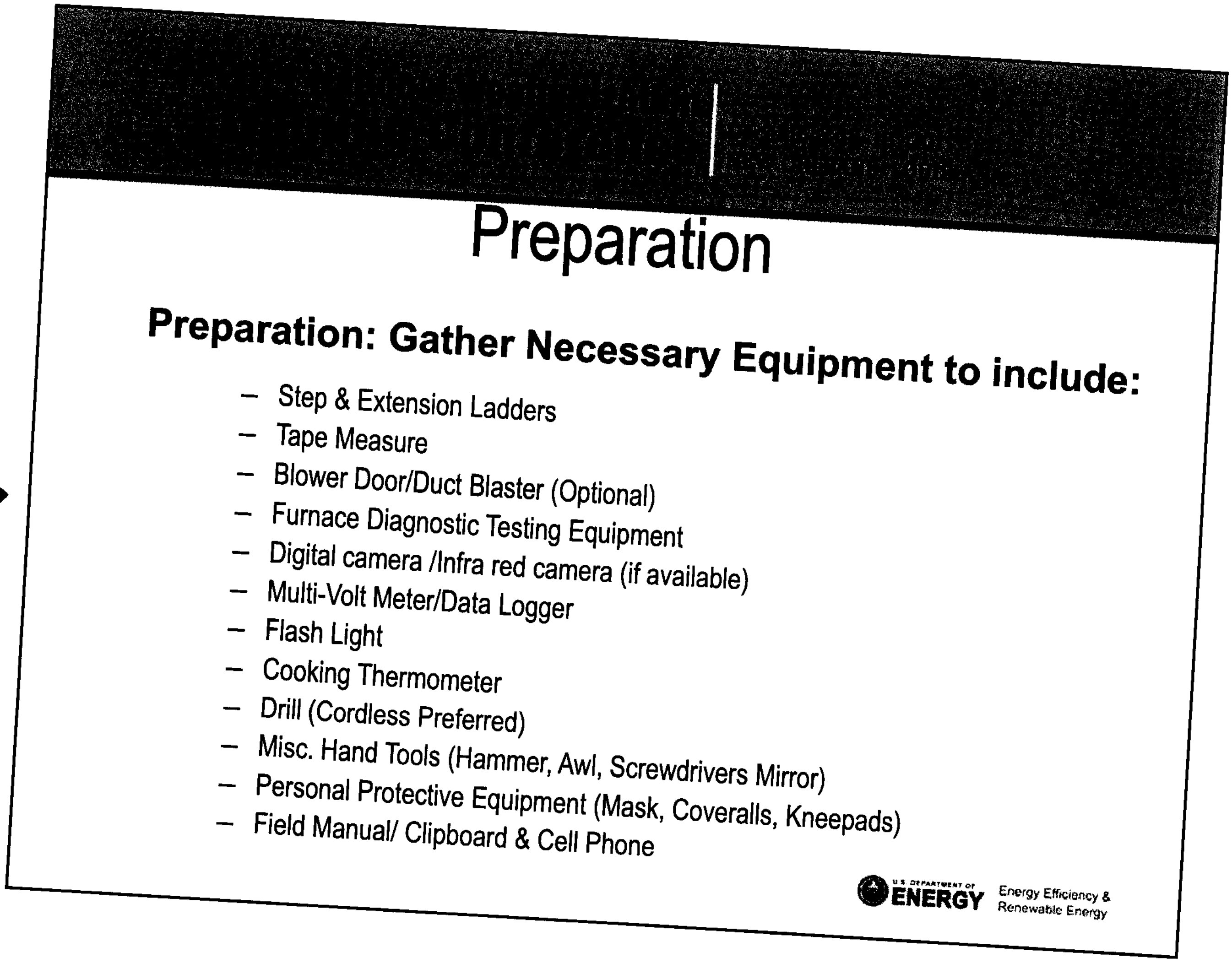
Step 1 – Preparation

- Gather information about Client
  - – Determine location/address
    Use Map Quest/GPS if not familiar with area
  - – Job Work Order Sheet
  - – Forms to be signed by Client (i.e. owner/renter agreement)
  - – EPA Forms and pamphlets
  - – Client Education handouts
  - – Other necessary Agency forms



Preparation

Preparation: Gather Necessary Equipment to include:

- Step & Extension Ladders
- Tape Measure
- Blower Door/Duct Blaster (Optional)
- Furnace Diagnostic Testing Equipment
- Digital camera /Infra red camera (if available)
- Multi-Volt Meter/Data Logger
- Flash Light
- Cooking Thermometer
- Drill (Cordless Preferred)
- Misc. Hand Tools (Hammer, Awl, Screwdrivers Mirror)
- Personal Protective Equipment (Mask, Coveralls, Kneepads)
- Field Manual/ Clipboard & Cell Phone

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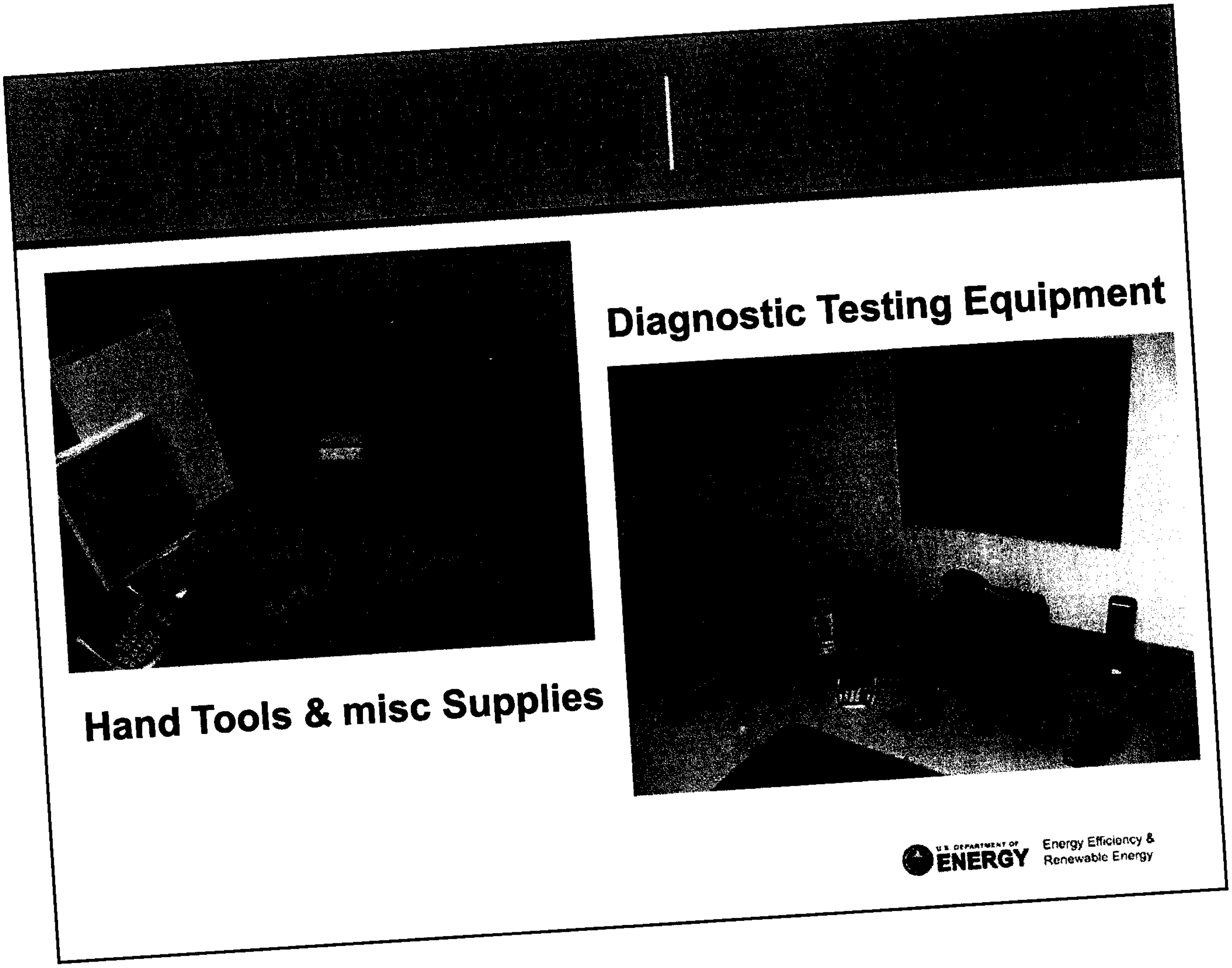

Diagnostic Testing Equipment

Hand Tools & misc Supplies

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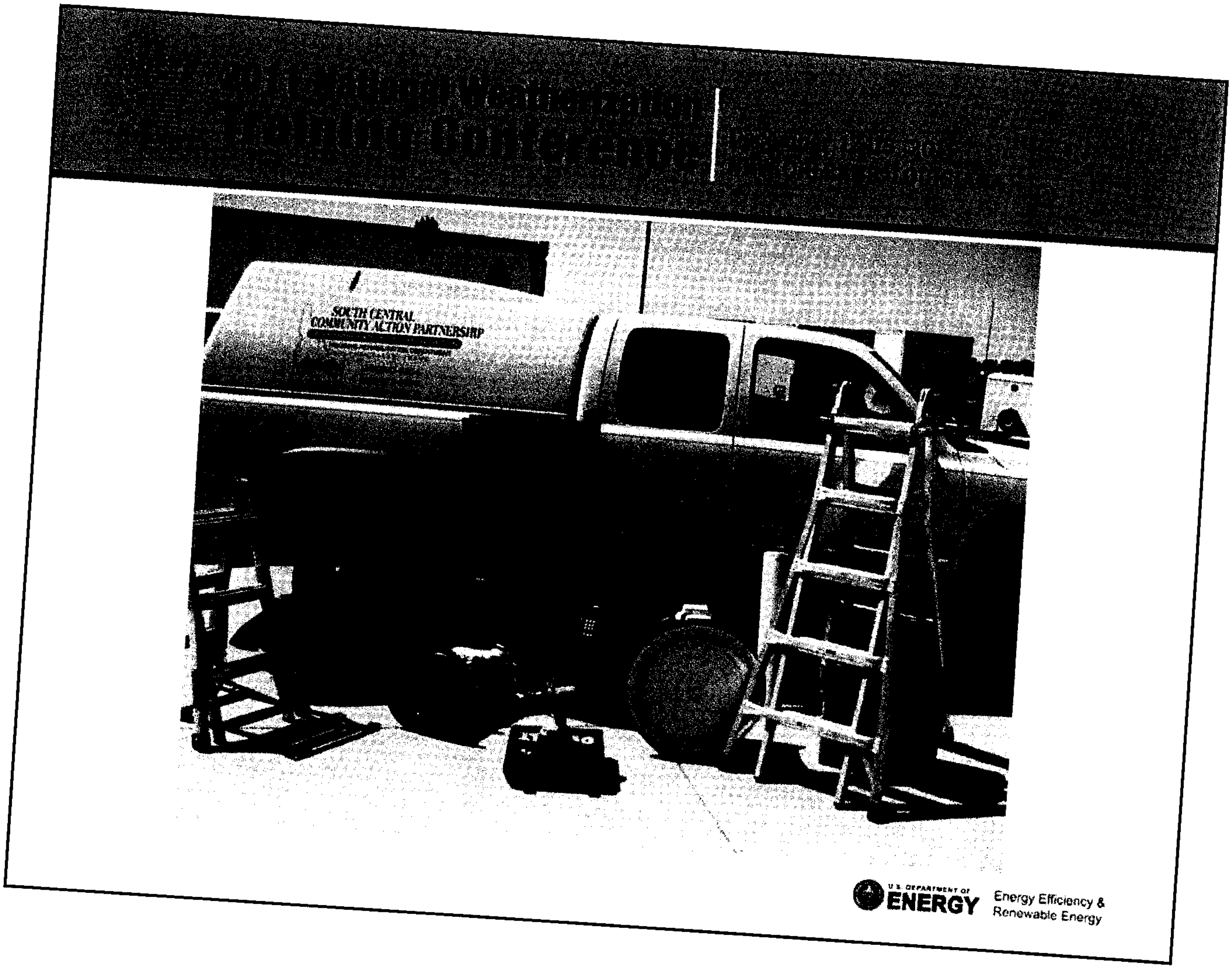

2011 National Weatherization Training Conference

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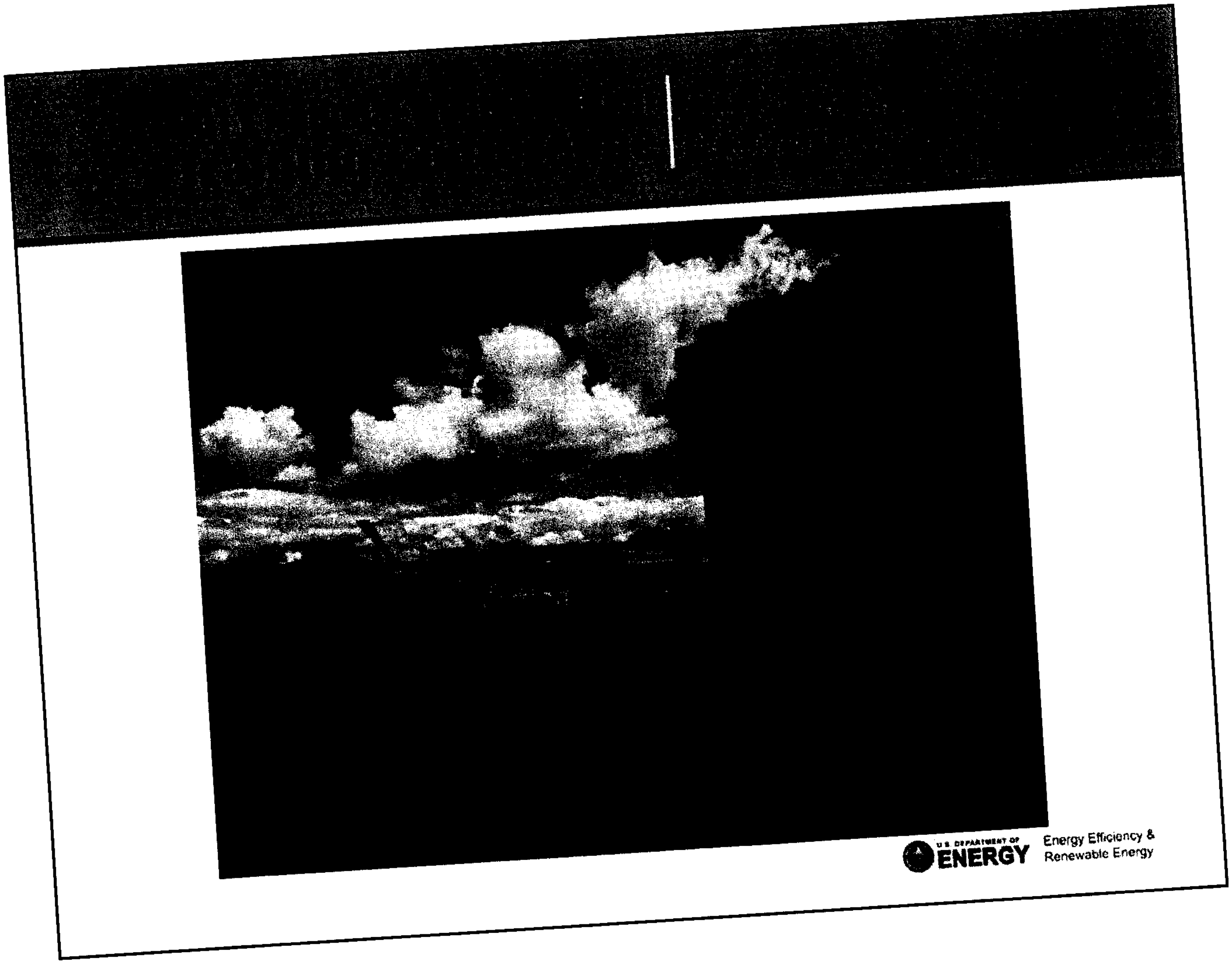

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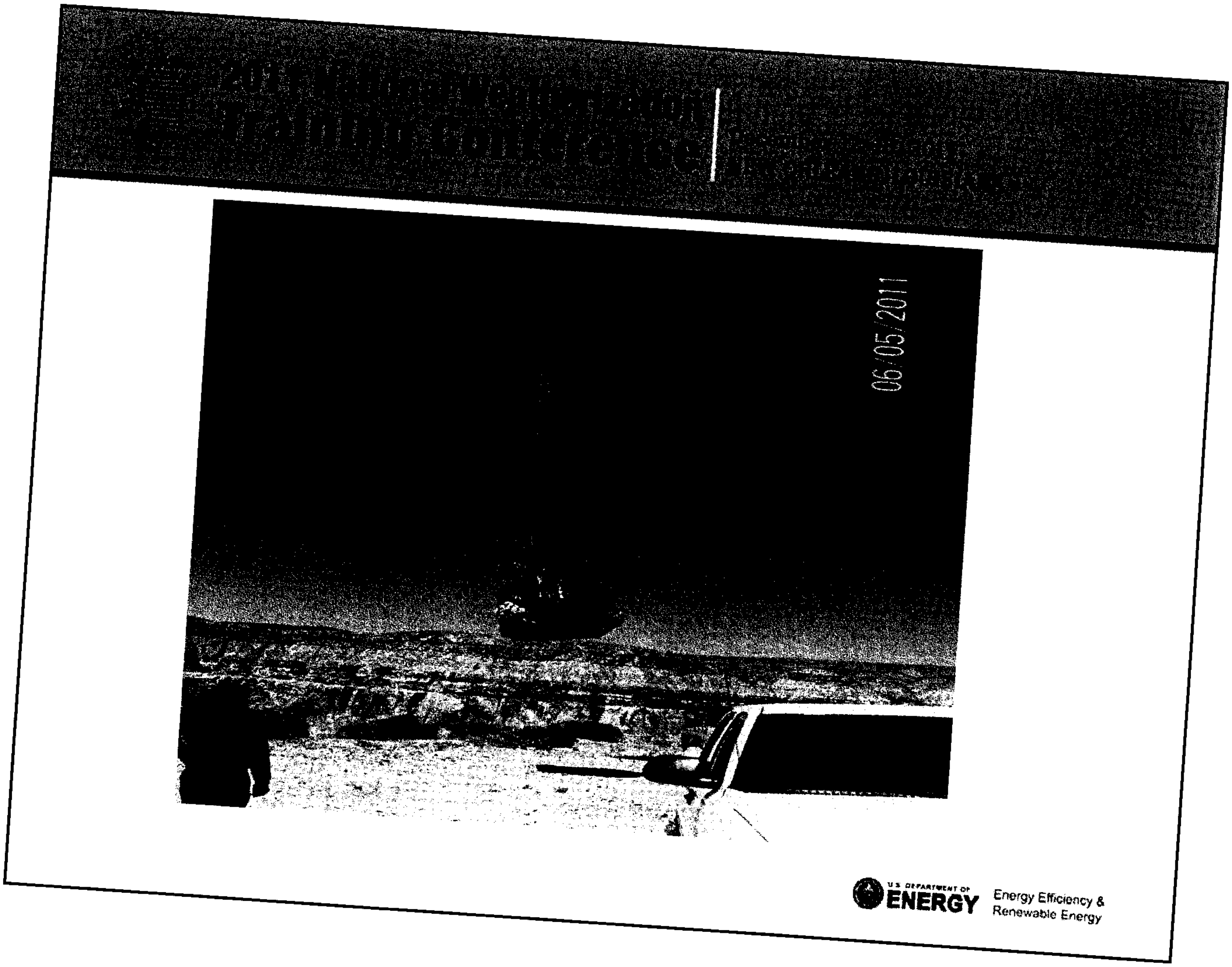

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Step 2 – Home Visit

- Introduction
  - Introduce yourself and provide client with audit plan
  - Present energy educational pamphlets to client
  - Discuss risks from lead base paint, mold and moisture
  - Give Client an overview of what will be done with Lead Safe Work Practices to assure their safety

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2011 National Weatherization Training Conference

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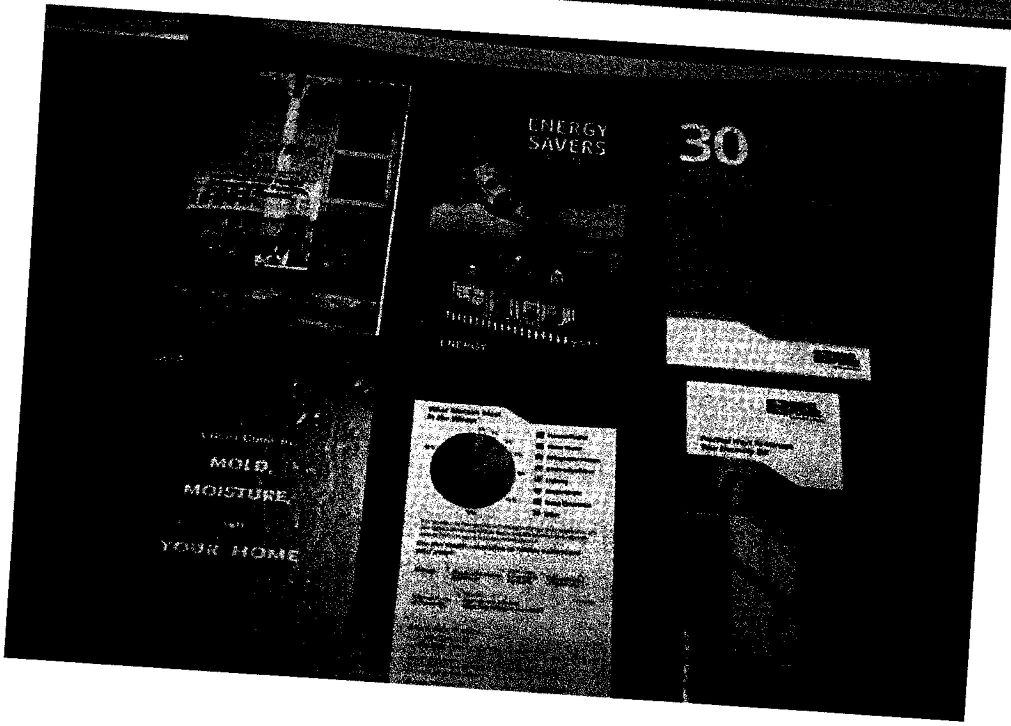

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Step 3 – Client Concerns

- Ask Client if there specific problems or concerns relating to their home.

Try to keep concerns to house directed to energy related issues only.

In some cases you will hear their life story.~ Be patient

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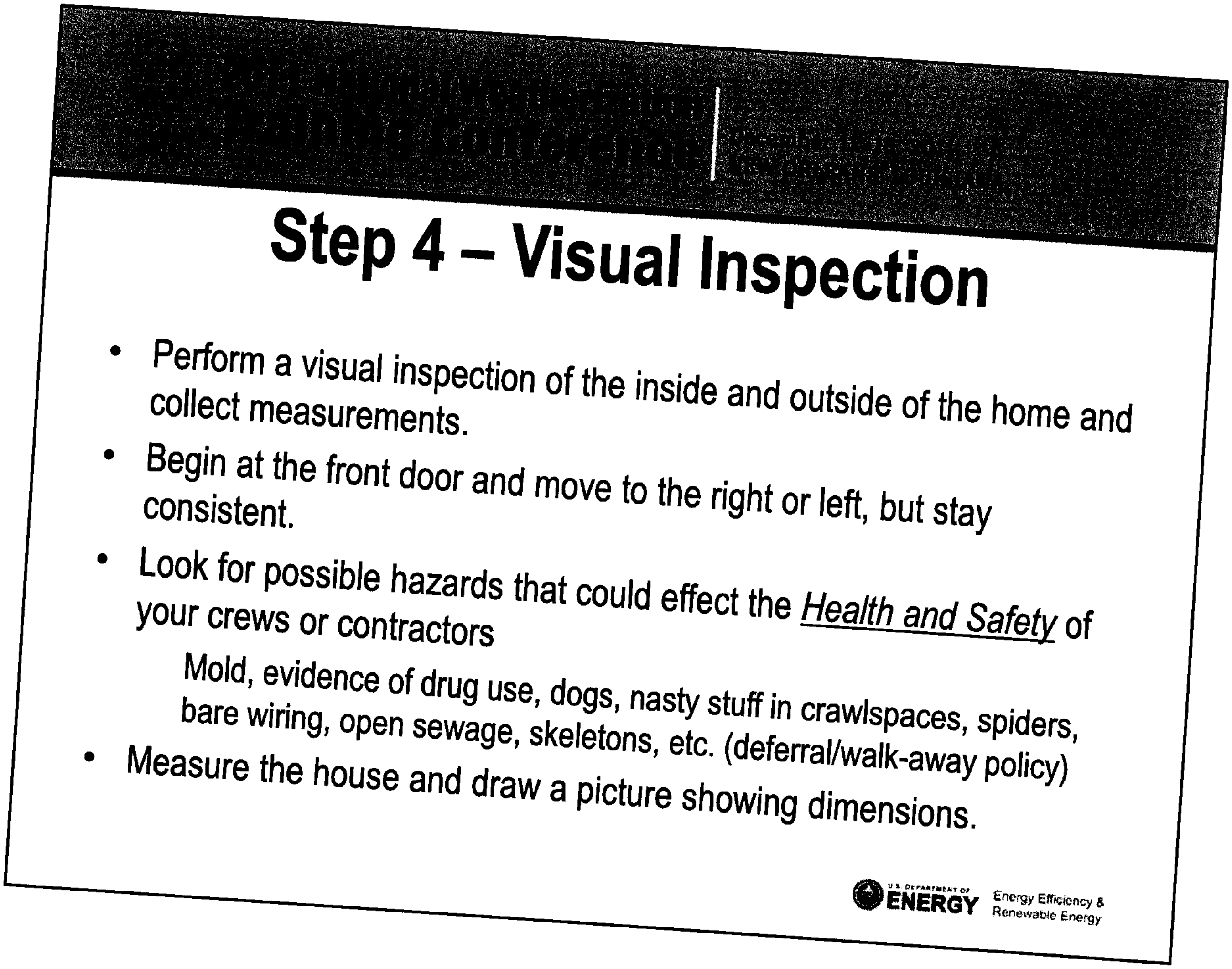

Step 4 – Visual Inspection

- Perform a visual inspection of the inside and outside of the home and collect measurements.
- Begin at the front door and move to the right or left, but stay consistent.
- Look for possible hazards that could effect the *Health and Safety* of your crews or contractors
  - Mold, evidence of drug use, dogs, nasty stuff in crawlspaces, spiders, bare wiring, open sewage, skeletons, etc. (deferral/walk-away policy)
- Measure the house and draw a picture showing dimensions.

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House Information & Measurements

- Collect information on the following:
  - Windows
    - Type? Condition? U-Value?
    - With or Without Storm Windows?
    - Measure Each Window
  - Doors
    - Type? Condition? U-Value?
    - With or Without Storm Door?
    - Measure Each Door

Collect Information

- Walls
    - Type of Siding?
    - Condition?
    - With or Without Insulation?
    - If Insulation – What Type?
    - How Much?
    - R-Value?
    - Wiring? (Knob & Tube, Romex)
    - Other Possible Problems/Issues

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Collect Information

- Inspect Roof
  - Condition?
  - Ventilation?
  - Type?
  - Size?
  - How Many?
- Inspect Attic
  - Type of Insulation?
  - How Much?
  - Heat Producing Devices? (Flues, Recess Lights, Fans)
  - Bypasses?
  - Other Possible Problems/Issues

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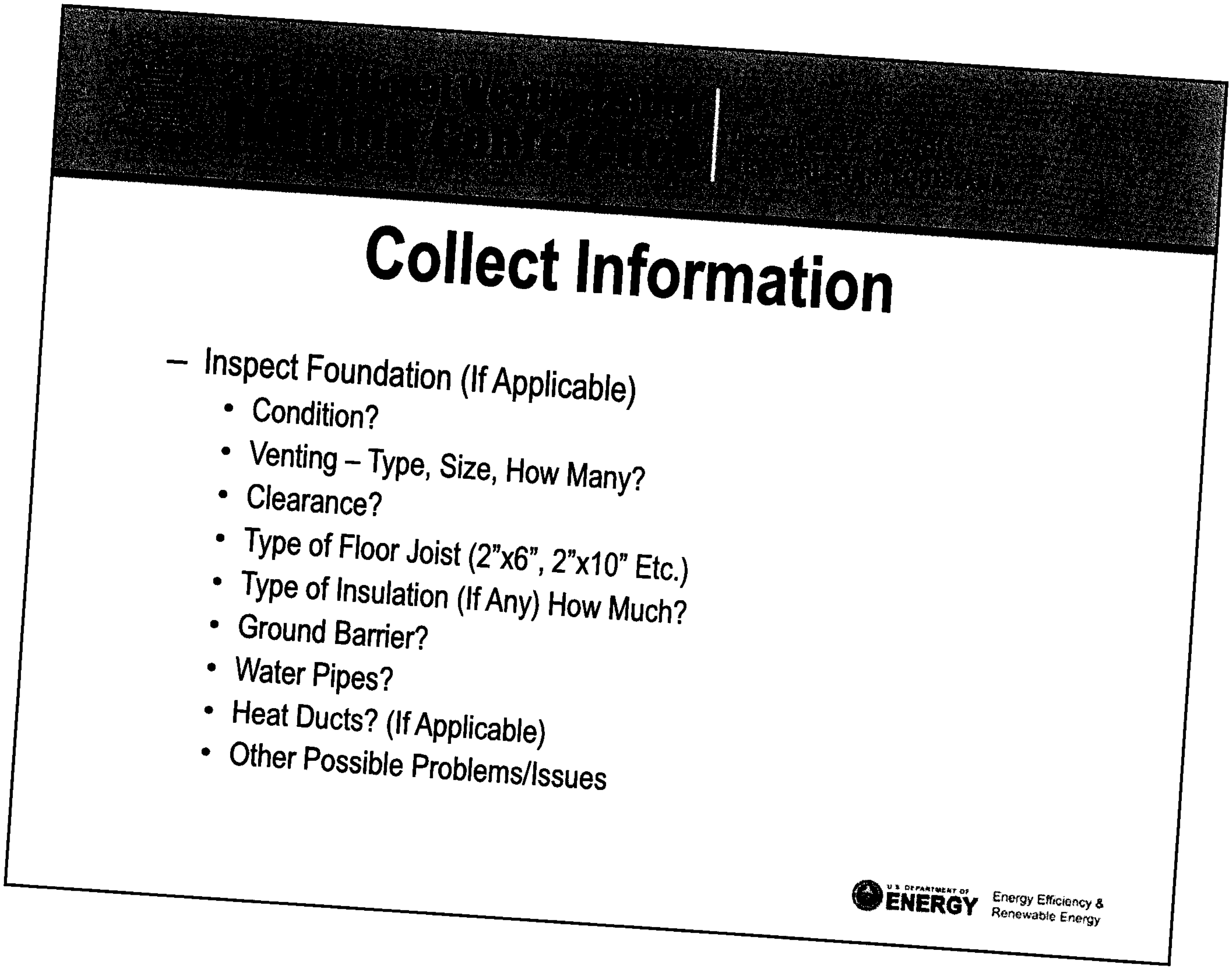

Collect Information

- Inspect Foundation (If Applicable)
  - Condition?
  - Venting – Type, Size, How Many?
  - Clearance?
  - Type of Floor Joist (2"x6", 2"x10" Etc.)
  - Type of Insulation (If Any) How Much?
  - Ground Barrier?
  - Water Pipes?
  - Heat Ducts? (If Applicable)
  - Other Possible Problems/Issues

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Heating System

- Type?
- Condition?
- Check T-Stat for Heat Anticipator Setting
- Fire Up Furnace
- Complete Diagnostic Testing
  - Combustion Fired Units– CO Analyzer, Draft Test (Coal, Oil, Gas, Wood, Propane)
  - Oil – Perform Smoke Test First
  - Electric – Volt/Amp Meter

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Water Heater, Blower Door & Duct Blaster

- Test
  - Type?
  - Condition?
  - If Electric – Test Elements / T-Stat
  - If Gas – Test for Draft and CO
- Run Blower Door Test
- Run Duct Blaster Test (if Applicable)

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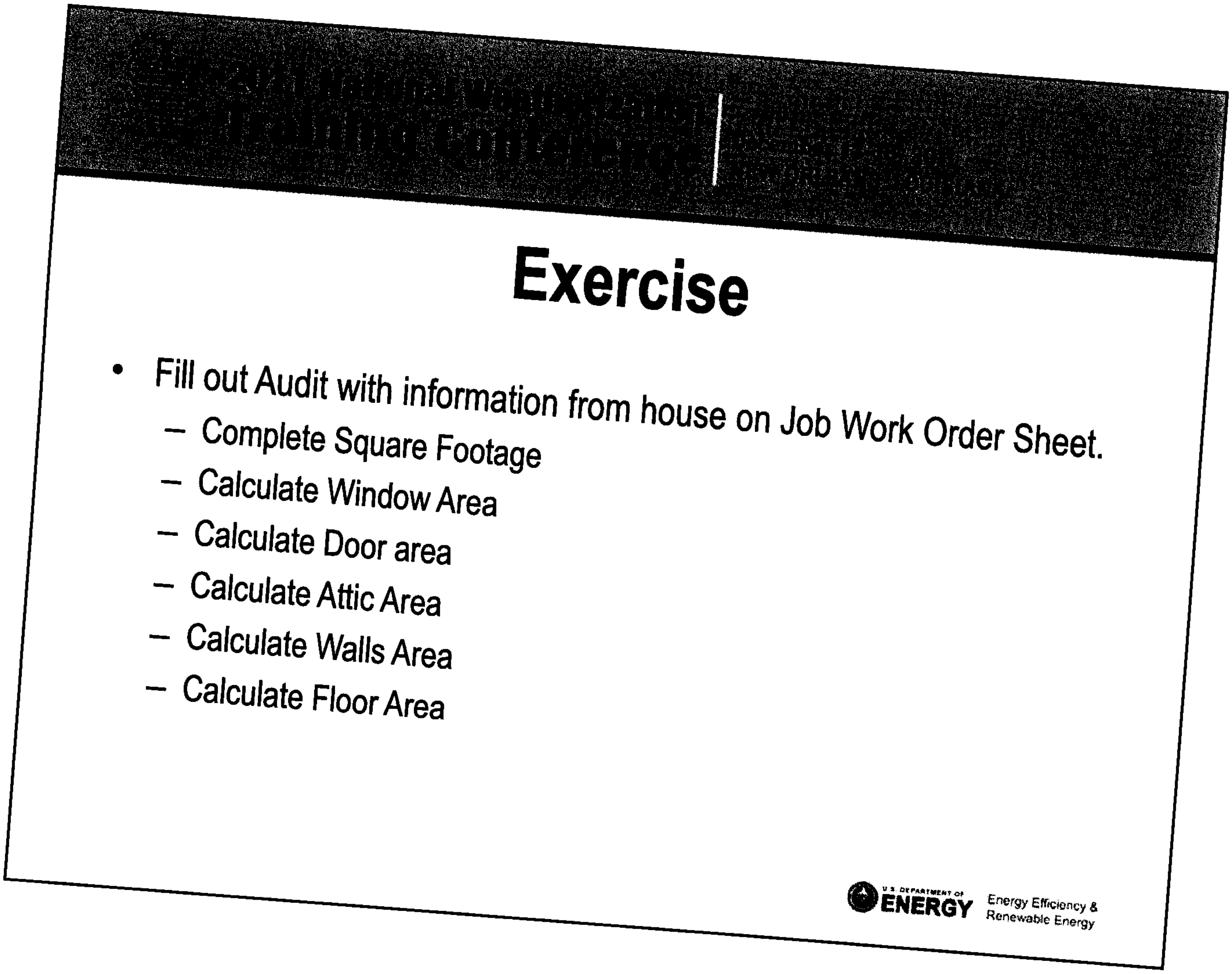
Wrap Up

- Inform Client of your findings and what you project to do to make their home more energy efficient.

- Return to office and…

put it all together



2011 National Weatherization
Training Conference

Exercise

- Fill out Audit with information from house on Job Work Order Sheet.
  - Complete Square Footage
  - Calculate Window Area
  - Calculate Door area
  - Calculate Attic Area
  - Calculate Walls Area
  - Calculate Floor Area

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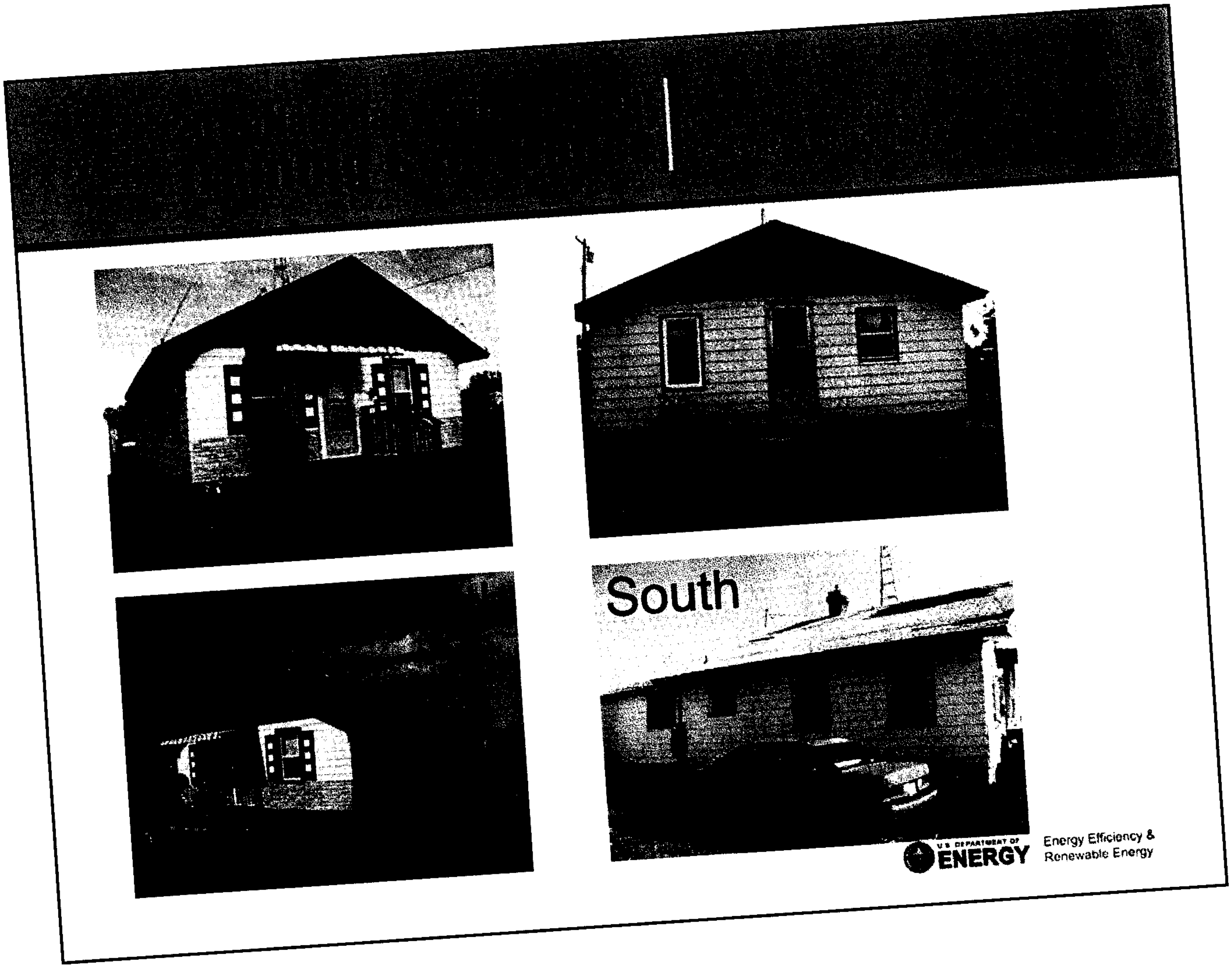

South

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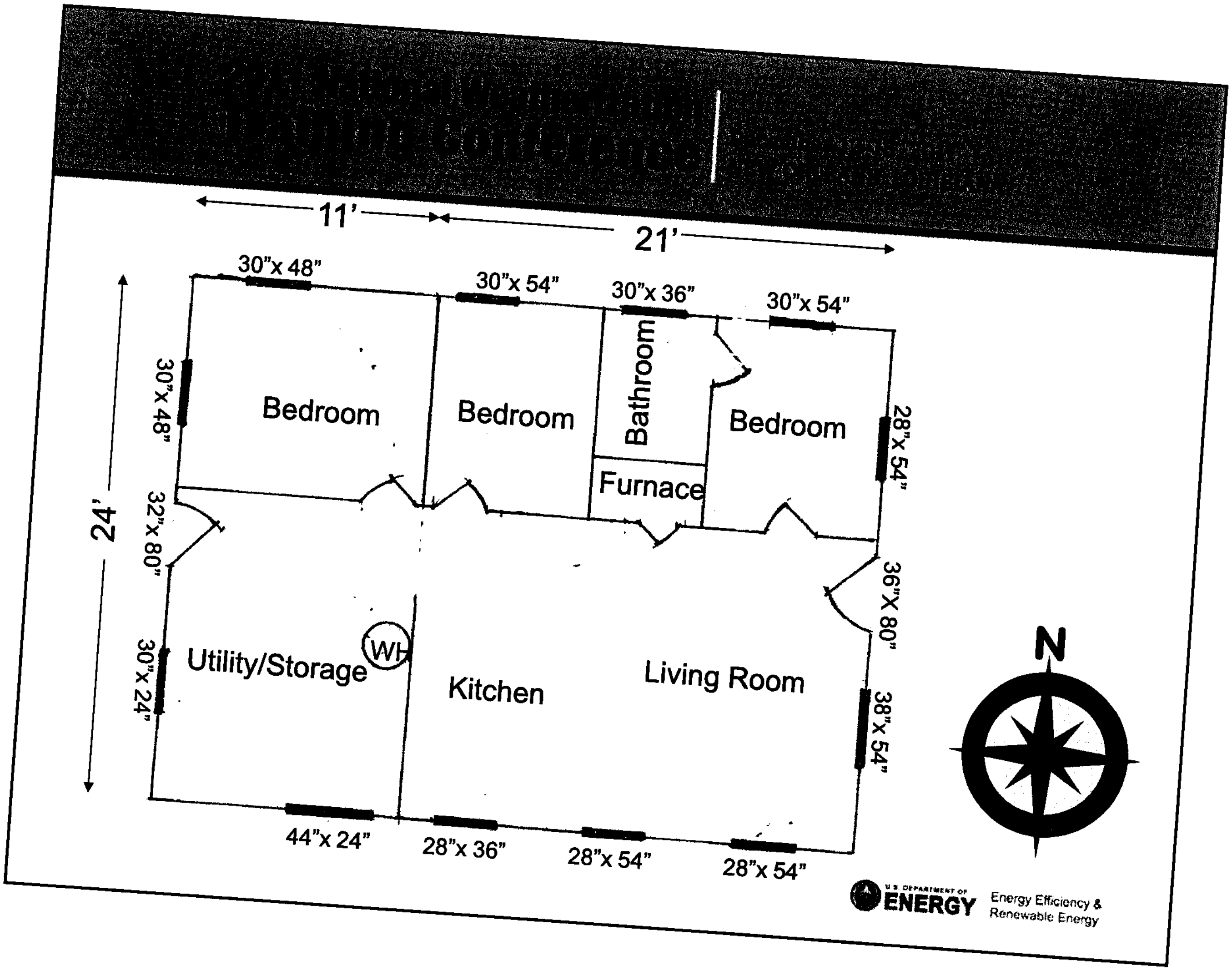

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11'
21'
24'
30"x 48"
30"x 54"
30"x 36"
30"x 54"
30"x 48"
28"x 54"
32"x 80"
36"X 80"
30"x 24"
38"x 54"
44"x 24"
28"x 36"
28"x 54"
28"x 54"
Bedroom
Bedroom
Bathroom
Bedroom
Furnace
Utility/Storage
WH
Kitchen
Living Room
N
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House Characteristics

- Ranch Style w/crawlspace, Twin Falls, ID
  - Built in 1951
  - Siding Metal No Insulation (Nothing Between Steel and Wood)
  - Walls 11'x24'x7' 2"x4" Studs
    21'x24'x8' 2"x4" Studs
  - Attic 3" Redwood Shavings R-4
    3" Blown fiberglass R-7
  - Venting 3-12"x24" Gable Vents
    3-9" Roof Vents
  - Foundation - 6" Concrete Foundation with 4-8"x10" Foundation Vents
  - Floor – 3' High Crawlspace – 2"x6" Joist – 24" OC – 0 Insulation and no Ground Barrier
  - Sub-Floor – Single Layer with Carpet

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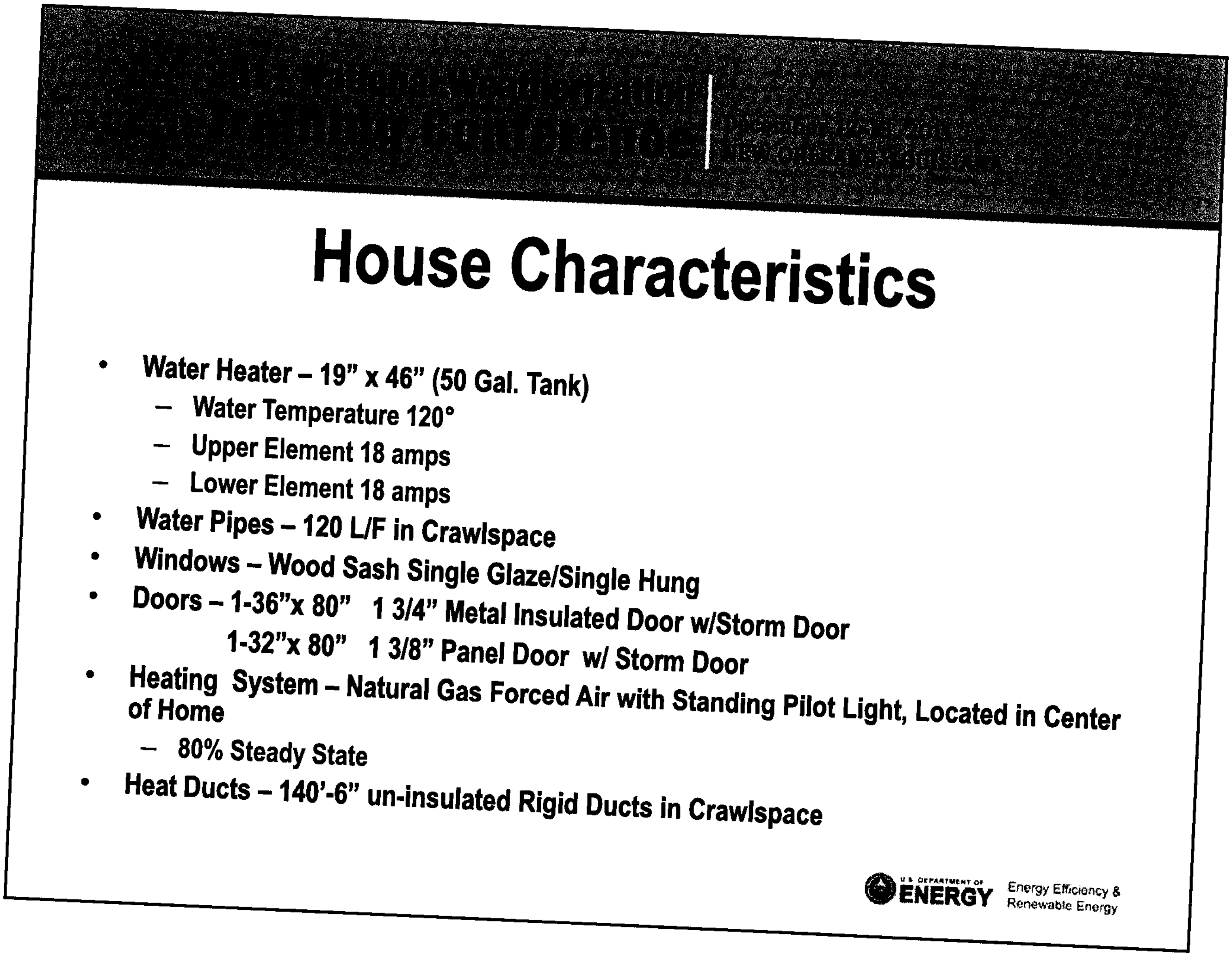

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House Characteristics

- Water Heater – 19" x 46" (50 Gal. Tank)
  - Water Temperature 120°
  - Upper Element 18 amps
  - Lower Element 18 amps
- Water Pipes – 120 L/F in Crawlspace
- Windows – Wood Sash Single Glaze/Single Hung
- Doors – 1-36"x 80" 1 3/4" Metal Insulated Door w/Storm Door
  1-32"x 80" 1 3/8" Panel Door w/ Storm Door
- Heating System – Natural Gas Forced Air with Standing Pilot Light, Located in Center of Home
  - 80% Steady State
- Heat Ducts – 140'-6" un-insulated Rigid Ducts in Crawlspace

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Price List

- Materials Price List

Cellulose Insulation	$4.95 per 30# Bag
R-19 Fiberglass	$15.00 per Roll (49 sq ft Roll)
R-11 Vinyl Duct Wrap Insulation	$60.00 per Roll (4'x50' Roll)
Tie Straps	$ .27 per Strap
Duct Mastic	$19.00 per Gallon
R-4 Tubular Pipe Insulation	$ .61 per L/F (6' Lengths)
6 mil Visqueen (Black)	$41.00 (10'x100' Roll)
Wood Lath	$11.00 per bundle (50 Pcs)
1 ¾" Metal Insulated Pre-Hung Door	$127.00 (36"x80")
1 ¾" Metal Insulated Pre-Hung Door	$127.00 (32"x80")
Keyed Entrance	$8.75 ea
Vinyl Insulated Window	$9.88 per sq ft

• Labor Cost	$18.00 per Hour
• Overhead	$85.00 per Job

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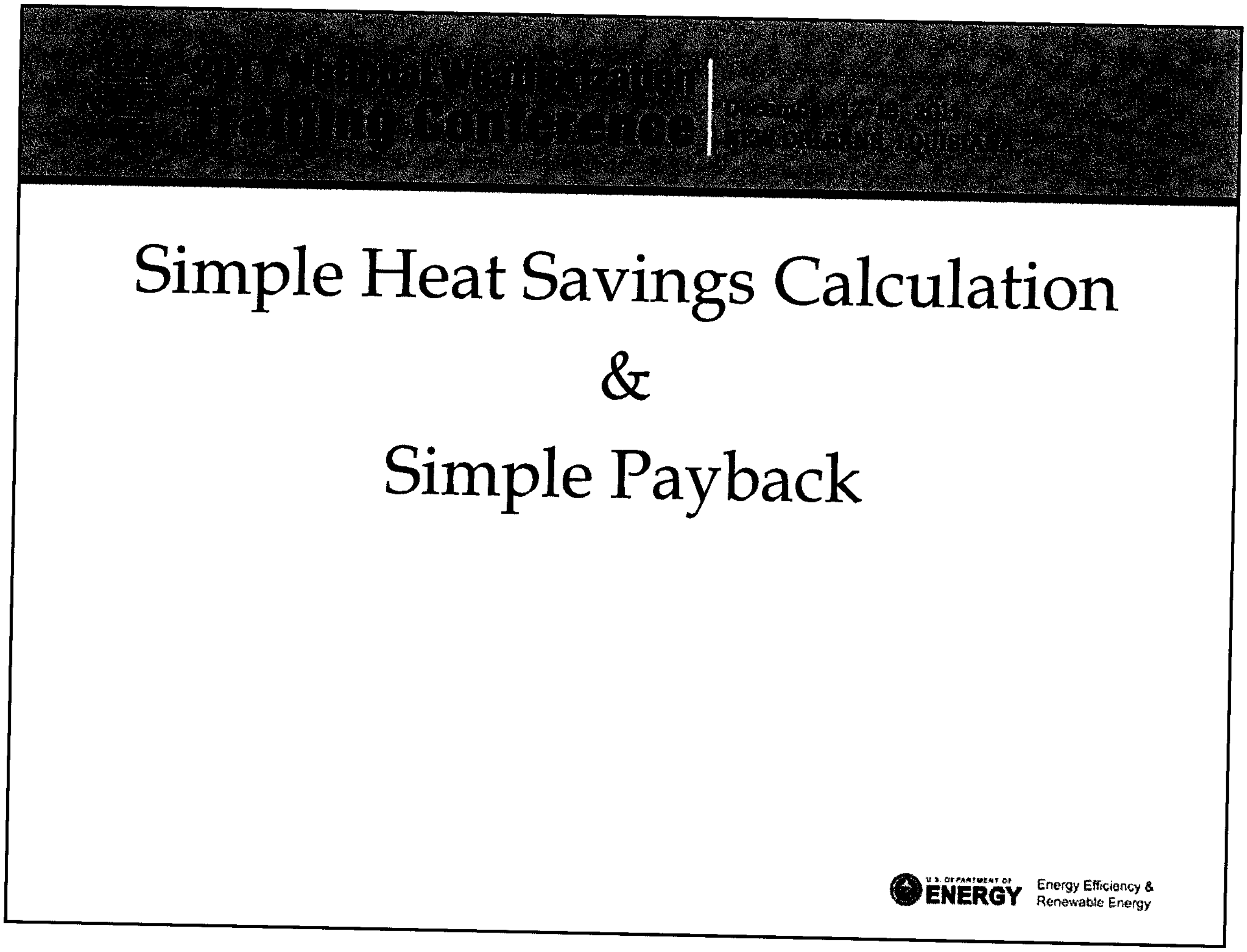

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Simple Heat Savings Calculation

&

Simple Payback

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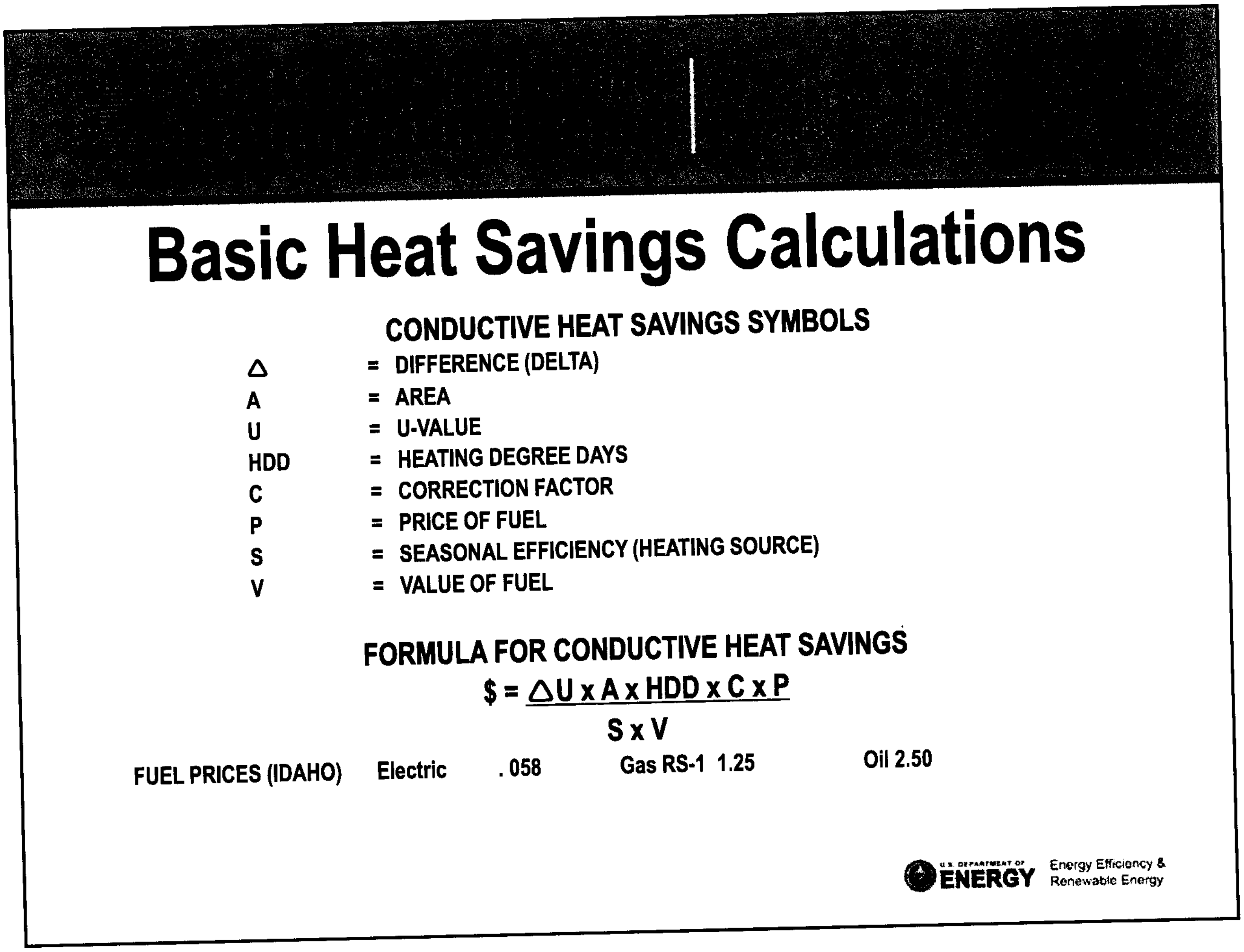

Basic Heat Savings Calculations

CONDUCTIVE HEAT SAVINGS SYMBOLS

△ = DIFFERENCE (DELTA)
A = AREA
U = U-VALUE
HDD = HEATING DEGREE DAYS
C = CORRECTION FACTOR
P = PRICE OF FUEL
S = SEASONAL EFFICIENCY (HEATING SOURCE)
V = VALUE OF FUEL

FORMULA FOR CONDUCTIVE HEAT SAVINGS

$$\$ = \frac{\Delta U \times A \times HDD \times C \times P}{S \times V}$$

FUEL PRICES (IDAHO) Electric . 058 Gas RS-1 1.25 Oil 2.50

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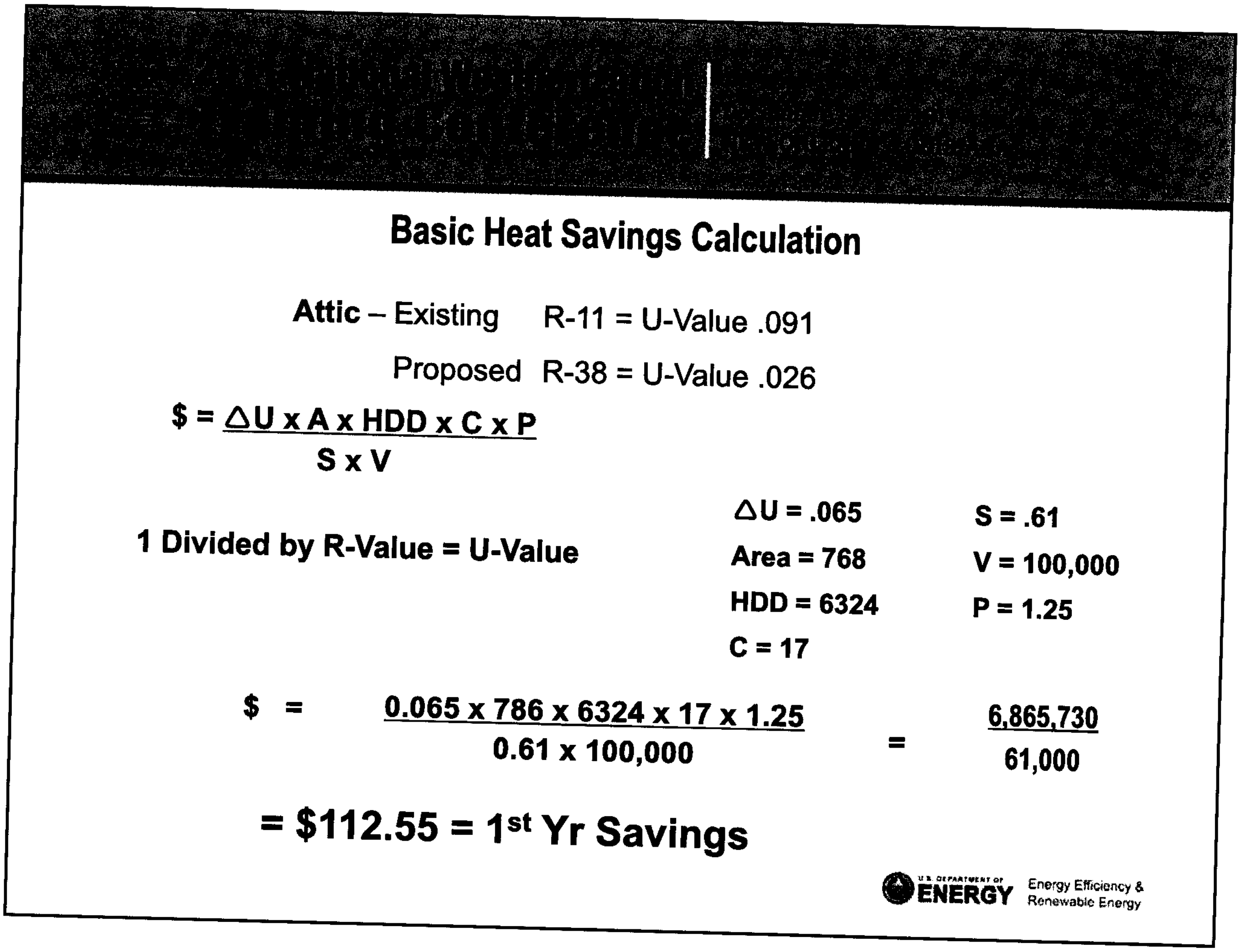

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Basic Heat Savings Calculation

Attic – Existing R-11 = U-Value .091

Proposed R-38 = U-Value .026

$$\$ = \frac{\Delta U \times A \times HDD \times C \times P}{S \times V}$$

1 Divided by R-Value = U-Value

ΔU = .065
Area = 768
HDD = 6324
C = 17

S = .61
V = 100,000
P = 1.25

$$\$ = \frac{0.065 \times 786 \times 6324 \times 17 \times 1.25}{0.61 \times 100{,}000} = \frac{6{,}865{,}730}{61{,}000}$$

= $112.55 = 1st Yr Savings

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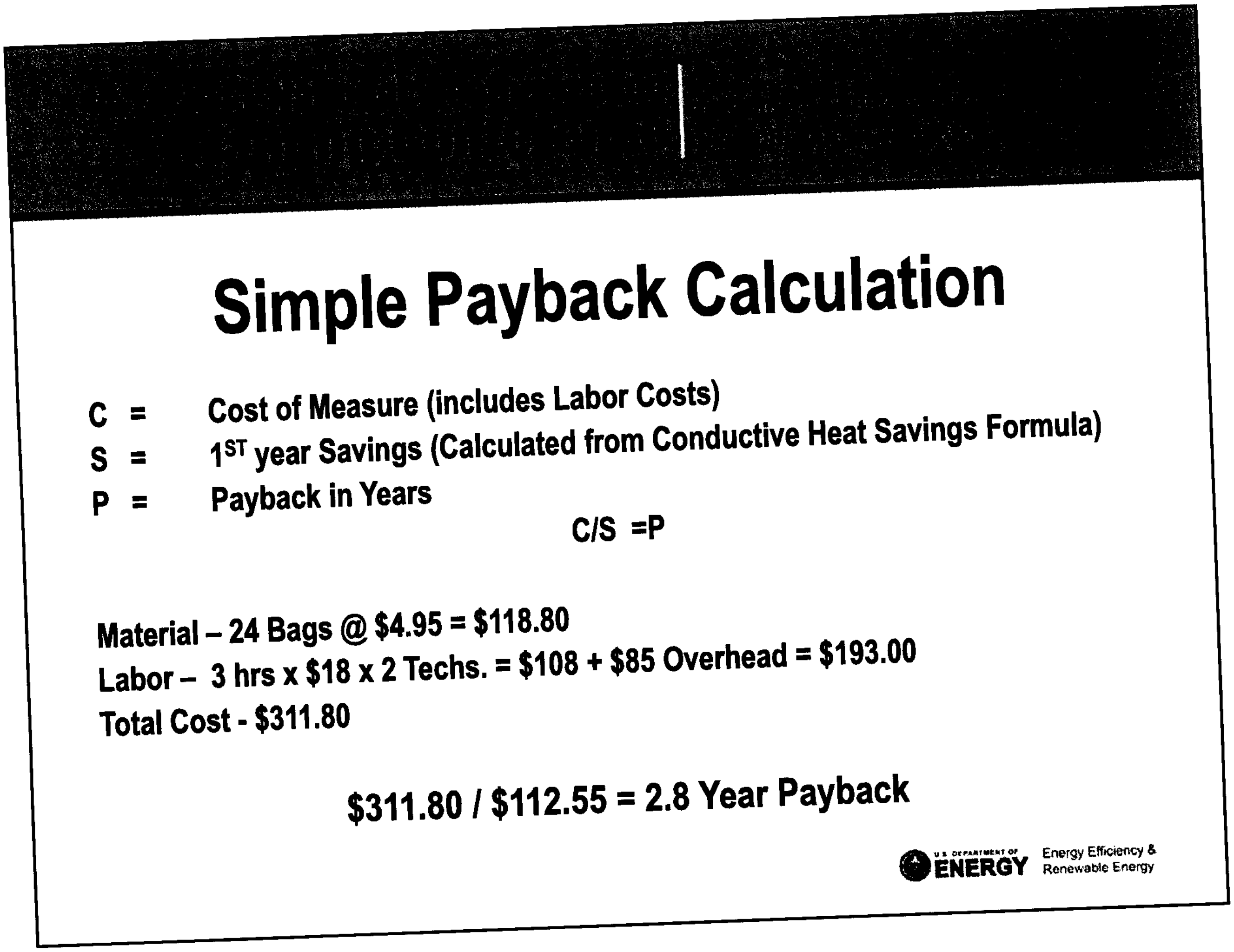

Simple Payback Calculation

C = Cost of Measure (includes Labor Costs)
S = 1^{ST} year Savings (Calculated from Conductive Heat Savings Formula)
P = Payback in Years

C/S =P

Material – 24 Bags @ $4.95 = $118.80
Labor – 3 hrs x $18 x 2 Techs. = $108 + $85 Overhead = $193.00
Total Cost - $311.80

$311.80 / $112.55 = 2.8 Year Payback

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Basic Heat Savings Calculation

Walls – Existing No insulation = U-Value 0.189
Proposed R-13 = U-Value 0.077

Total Walls	=	**850 sq ft**
Less Windows	-	115 sq ft
Less Doors	-	38 sq ft
Less Studs	-	105 sq ft
Total Area		**592 sq ft**

$$\$ = \frac{\Delta U \times A \times HDD \times C \times P}{S \times V}$$

$\Delta U = .112$
Area = 592
HDD = 6324
C = 17
S = .61
V = 100,000
P = 1.25

$$\$ = \frac{.112 \times 592 \times 6324 \times 17 \times 1.25}{0.61 \times 100{,}000} = \frac{8{,}910{,}263}{61{,}000}$$

= $146.07 = 1st Yr Savings

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Simple Payback Calculation

C = Cost of Measure (includes Labor Costs)
S = 1^{ST} year Savings (Calculated from Conductive Heat Savings Formula)
P = Payback in Years

C/S =P

Material – 17 Bags @ $4.95 = $84.15
Labor – 8 hrs x $18 x 2 Techs. = $288 + $85 Overhead = $373.00
Total Cost - $457.15

$457.15 / $146.07 = 3.13 Year Payback

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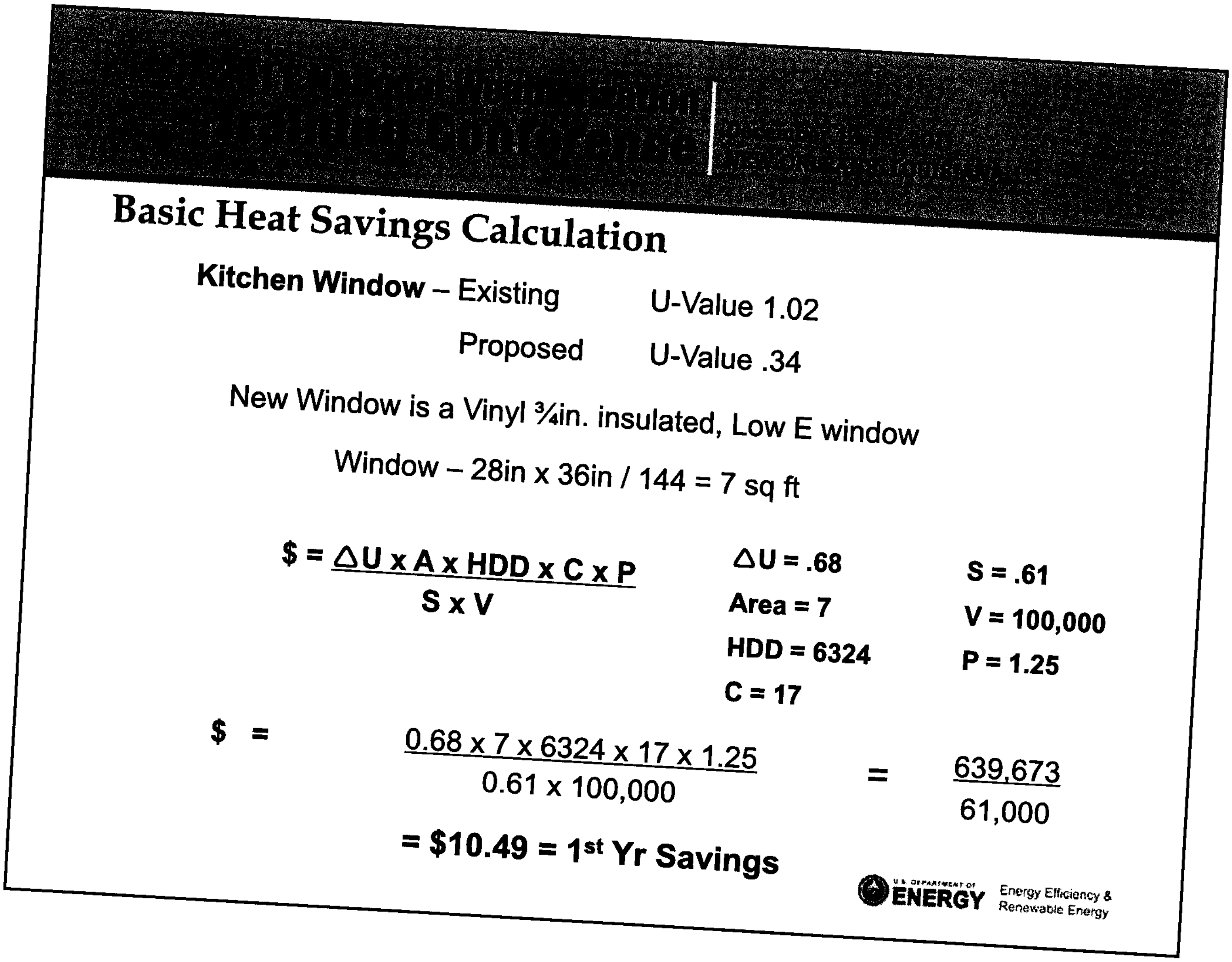

Basic Heat Savings Calculation

Kitchen Window – Existing U-Value 1.02

Proposed U-Value .34

New Window is a Vinyl ¾in. insulated, Low E window

Window – 28in x 36in / 144 = 7 sq ft

$$\$ = \frac{\Delta U \times A \times HDD \times C \times P}{S \times V}$$

$\Delta U = .68$

Area = 7

HDD = 6324

C = 17

S = .61

V = 100,000

P = 1.25

$$\$ = \frac{0.68 \times 7 \times 6324 \times 17 \times 1.25}{0.61 \times 100{,}000} = \frac{639{,}673}{61{,}000}$$

= \$10.49 = 1st Yr Savings

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Simple Payback Calculation

C = Cost of Measure (includes Labor Costs)
S = 1^{ST} year Savings (Calculated from Conductive Heat Savings Formula)
P = Payback in Years

C/S =P

Material – \$9.50 x 7 sq ft = \$66.50
Labor – 1 ½ hrs x \$18 x 1 Tech. = \$27 + \$85 Overhead = \$112.00
Total Cost - \$178.50

\$178.50 / \$10.49 = 17 Year Payback

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